Comparing Peak Frequency to Shear Wave Velocity Models in South Korea

Joo-hwan Cha, Young-taek Hong, Eric Yee *
Department of NPP Engineering, KEPCO International Nuclear Graduate School,
658-91 Haemaji-ro, Seosaeng-myeon, Ulju-gun, Ulsan 45014
**Corresponding author: eric.yee@kings.ac.kr*

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1. Introduction

After the 2016 Gyeongju and 2017 Pohang earthquakes in South Korea, society and industry has had a renewed interest in earthquake engineering. One of the reasons is perhaps due to the proximity these earthquakes and their aftershocks were to multiple nuclear power plant complexes, with Figure 1 showing the earthquake epicenters and the locations of such nuclear power plant complexes.

Fig. 1. Map of South Korean nuclear power plant complexes and the epicenters for the 2016 Gyeongju and 2017 Pohang earthquakes. Note the proximity of the earthquakes to Saeul and Wolsong nuclear power plants.

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 generally composed of multiple models describing the factors that affect ground shaking, some of which involve subsurface material properties [1-2]. Although a majority of nuclear power plant power block foundations are founded on hard rock sites, some portions are not. Additionally, not all of the supporting infrastructure is on hard rock.

To better understand subsurface material properties, a variety of physical testing and analysis techniques have been developed over the years. One such technique involves relating the mean shear wave velocity of the earth materials in the upper 30 m, V_{S30}, to a site-specific peak frequency, f_p [3-4]. If not directly measured, these peak frequencies can be estimated using a horizontal-to-vertical spectral ratio method. The horizontal-to-vertical spectral ratio is typically calculated as the ratio of the vertical response spectra to the horizontal response spectra. Response spectra are derived from ground motions at the site. There are several models that correlate f_p with V_{S30} from response spectra [5-7]. This study attempts to compare the models to ascertain their effectiveness.

2. Methods and Results

For this study, horizontal-to-vertical spectral ratios are estimated using several South Korean earthquake ground motions recorded by the Korea Institute of Geoscience and Mineral Resources, with the seismic observation stations shown in Figure 2.

Fig. 2. Korea Institute of Geoscience and Mineral Resources seismic observation stations.

Horizontal-to-vertical spectral ratios were calculated from the stations that recorded major earthquakes. The list of earthquakes was taken from the Korea Meteorological Administration as well as the International Seismological Centre. Events include the 2016 Gyeongju and 2017 Pohang earthquakes. However, some sensors were installed after the events and thus do not have waveforms to process. An example horizontal-

to-vertical spectral ratio is shown in Figure 3, which is the average of all events available.

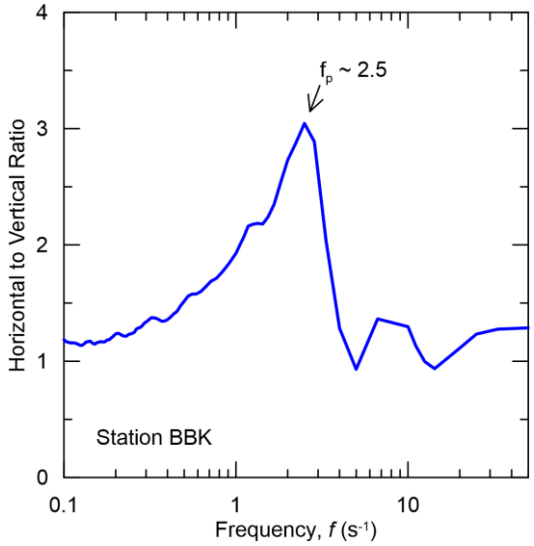

Fig. 3. The average horizontal-to-vertical spectral ratio for station named BBK. Peak frequency is noted at 2.5.

Along with the spectral ratio derived peak frequencies, the corresponding field measured shallow shear wave velocities are compiled to form a dataset for comparison. Although there may be other shear wave velocity data sets, this study only considered field measured data at the locations of interest for vertically propagating shear waves, i.e. suspension logging. This dataset is compared to several methods developed for global use. For ease of use and purposes of identification, these models will be called GA14 [5], HA16 [6], and YH20 [7]. Figure 4 shows the results of this comparison. The result suggest the working dataset is small and that the global models did not perform as well, but a model strictly based on central and eastern North America did relatively well.

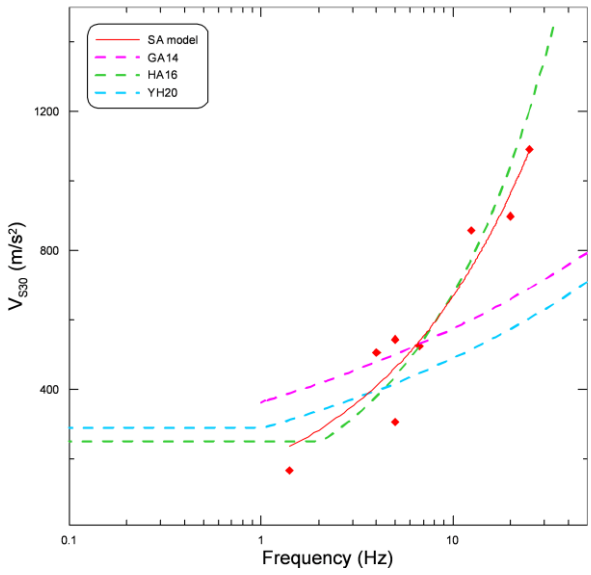

Fig. 4. Comparison of models estimating V_{S30} (GA14, HA16, and YH20) through horizontal-to-vertical spectral ratio.

Additional results show that there is a lack of local site-specific shear wave velocity data overall. There are also difficulties in identifying a peak frequency in several sites using these horizontal-to-vertical spectral ratio models and even when working the results are scattered.

3. Conclusions

These results suggest the global and American models used for accounting for the effects of strong ground shaking from earthquakes may not be applicable to the South Korean peninsula. Given how strict rules and regulations are when it comes to nuclear power projects, there may be a need to either gather more data for better comparisons or enough data to generate another model specific to the region.

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REFERENCES

[1] N. Abrahamson, W. Silva, R. Kamai. Summary of the ASK 14 ground motion relation for active crustal regions. Earthquake Spectra., Vol. 30, p. 1025, 2014.
[2] D. M. Boore, J. P. Stewart, E. Seyhan, G. M. Atkinson. NGA-West2 equations for predicting PGA, PGV, and 5% damped PSA for shallow crustal earthquakes Earthquake. Spectra.Vol. 30, p. 1057, 2014.
[3] M. Nogoshi, T. Igarashi. On the amplitude characteristics of microtremor (part 2). Journal of Seismological Society of Japan, Vol. 24, p. 26, 1971.
[4] F. Nagashima. S. Matsushima, H. Kawase, F. J. Sanchez-Sesma, T. Hayakawa, T. Satoh, M. Oshima. Application of horizontal-to-vertical spectral ratios of earthquake ground motions to identify subsurface structures at and around the K-NET site in Tohoku, Japan. Bulletin of the Seismological Society of America, Vol. 104, p. 2288, 2014.
[5] H. Ghofrani, and G. M. Atkinson, G.M. Site condition evaluation using horizontal-to-vertical response spectral ratios of earthquakes in the NGA-West 2 and Japanese databases. Soil Dynamics and Earthquake Engineering, Vol. 67, p. 30, 2014.
[6] B. Hassani, G. M. Atkinson. Applicability of the site fundamental frequency as a VS30 proxy for central and eastern North America. Bulletin of the Seismological Society of America, Vol. 106, p. 653, 2016.
[7] S. Yaghmaei-Sabegh, B. Hassani. Investigation of the relation between VS30 and site characteristics of Iran based on horizontal-to vertical spectral ratios. Soil Dynamics and Earthquake Engineering, Vol. 128, 2020.