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Systematic Evaluation of Horizontal-to-Vertical Earthquake Spectral Ratios in the Kansai Area

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1. Introduction

The site-specific earthquake motion observed on the ground surface is a result of source, path, and site effects. The site effects, e.g. local amplification and soil liquefaction, are caused by the wave propagation through the local sub-surface rock and soil layers and can be the origin of significant damage and casualties. Hence, site effects should be investigated especially in urban areas such as Osaka, Kyoto, and Nara basins.

A simple method to investigate the site-specific amplification factor is using Horizontal-to-Vertical (H/V) spectral ratios. The spectral ratios can be computed from three-component recordings of microtremors (Nogoshi and Igarashi 1971, Nakamura 1989) or local earthquakes (e.g. Lermo and Chávez-García 1993). Although wave fields investigated by these two approaches are not the same (diffuse wave field vs. upward body waves, respectively; e.g. Kawase et al. 2018), the H/V spectral peaks are likely to be correlated (but not equal) to local spectral amplification, i.e. resonance of local sub-surface lithological layers.

In this study, we performed a systematic evaluation of H/V earthquake spectral ratios at 449 sites from the inner Kansai area, which are covered by strong-motion measurements on the ground surface. Our advanced processing of various horizontal components resulted in a database of high-quality H/V spectral curves including the directional dependence.

2. Data and Processing

In this study, we use a total of 40515 three-component earthquake waveforms, which were recorded in the period 1994–2023 at 449 sites in the Kansai area by surface monitoring stations:

(1) operated by local governments (Kyoto-fu, Kyoto-shi, Nara-ken, Osaka-fu, Hyogo-ken, Shiga-ken, Wakayama-ken),

(2) K-NET, KiK-net (operated by the National Research Institute for Earth Science and Disaster Resilience, NIED 2019, Aoi et al. 2020),

(3) JMA Shindo-kei (operated by the Japan Meteorological Agency, https://www.jma.go.jp),

(4) operated by the Committee of Earthquake Observation and Research in the Kansai Area (CEORKA, http://www.ceorka.org),

(5) and stations operated by the Disaster Prevention Research Institute (DPRI) of Kyoto University (https://sms.dpri.kyoto-u.ac.jp).

The three-component waveform data were first rotated into transversal, radial, E-W, N-S, SE-NW, and NE-SW horizontal components of ground motion and processed similarly to the procedure by Hallo et al. (2022). The processing differs in the use of horizontal and vertical components at one location instead of horizontal components at two locations. Then, for each earthquake-station pair, we obtained:

(1) high-quality Fourier spectra of all components,

(2) frequency bands, in which spectra have values at least three times larger than the local seismic noise,

(3) H/V spectral curves for all horizontal components.

These properties were evaluated separately both from the strongest and coda waves. Finally, the individual earthquake-specific H/V curves were statistically evaluated within their reliable frequency bands (reliable bands are also earthquake-specific) to obtain representative site-specific high-quality H/V curves.

3. Results

The systematic processing of earthquake waveforms resulted in a database of H/V spectral curves within the frequency range of 0.08–30 Hz. The frequency range is limited by the sufficient signal-to-noise ratio and technical parameters of the recording system. The site-specific H/V curves above 10 Hz may, but may not, be contaminated by sensor housing effects; still, these effects can be suppressed by the statistic from transversal components of variously distributed earthquakes. Further, we can evaluate the directional dependence of H/V curves, because we systematically and separately analyze various horizontal components.

In Fig. 1, see example of results for the station 57B (JMA Shindo-kei), which is installed near the Uji City Hall (Kyoto-fu). The significant H/V peak at frequency 0.61 Hz is likely related to a local sedimentary layer and it has a strong directional dependence. In particular, it is prominent mostly in the N-S direction with the largest directional dependency factor γ (Matsushima et al. 2017) equal to 2.0 within the range of the H/V peak.

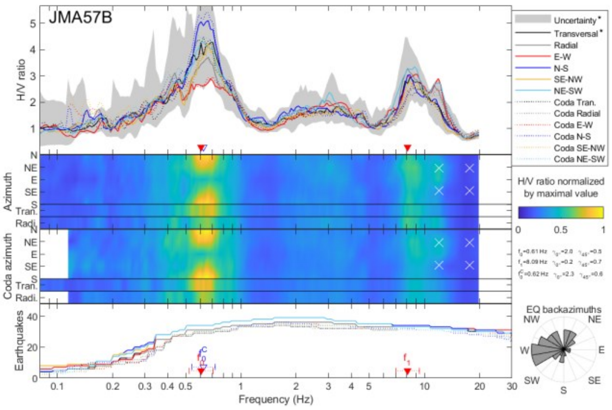

Figure 1. Example of the H/V earthquake ratio analysis at station 57B (JMA). The upper panel shows the H/V ratios of various horizontal components, middle panels show directionality of H/V peaks, and the bottom panel shows the number of contributing regional earthquakes.

4. Conclusions

Our database of high-quality H/V spectral curves can be valuable for future ground motion amplification studies in the Osaka, Kyoto, and Nara basins. In particular, frequency and directionality of fundamental H/V peak can be spatially correlated with the thickness and disposition of the sedimentary lithological layer.

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