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Proxies for site effect estimation: can statistics help us?

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The earthquake site response is one of the causes of different damage level at nearby sites. Its assessment is possibly based on empirical methods using the earthquake recordings. However, when limited resources and/or recorded earthquakes are not available, several proxies are used.

In this framework the standard spectral ratio (SSR) is considered the reference empirical method to detect amplification as a function of frequency, but other estimates can be easily obtained from noise measurements. The ambient noise is largely used to compute the Horizontal-to-Vertical Spectral Ratio (HVN) and the Rayleigh-wave dispersion curve (DC). The first method, HVN, realistically indicates the fundamental frequency but, for the majority of the worldwide-examined sites, its reliability in terms of amplitude is controversial. The dispersion curve, DC, instead, is inverted to obtain the shear-wave velocity profile below the station and to compute the average shear-wave velocity in the first 30 meters (Vs30); the Vs30 parameter is then used as a most common proxy of site effect, even though it is presently criticized because it cannot represent alone the main physics of site response.

Using a well-known statistical tool, the canonical correlation analysis, we verify and quantify the relationship between HVN and SSR measured at the same sites, and between DC and SSR computed for another database.

We studied the correlation between SSR and HVN using recordings from 64 sites worldwide and we show that linear combinations of the HVN amplitudes in different frequency intervals are significantly correlated to linear combinations of the SSR. These results can be used to estimate the expected SSR spectral ratio from the recorded HVN curve at sites located in the same investigated areas.

The canonical correlation between SSR and DC has been studied on a set of theoretical dispersion curves and transfer functions, computed from shear-wave velocity (Vs) profiles measured at more than 400 stations of the Japanese KiK-Net accelerometric network. The results indicate very encouraging qualitative statistical relationships between DC and site amplification for numerically derived SSR. Moreover, the Rayleigh-wave dispersion curve (DC) can provide information on site response due to soils deeper that 30 m not considered in the single Vs30 parameter.

The SSR evaluation has been tested by a cross validation procedure: the expected SSR at each validation site are in turn estimated by a weighted average of the SSR values measured at the other sites; the weights are properly set to account more for the sites with similar behaviour in terms of the canonical correlation results with HVN or DC.

To evaluate the goodness of the estimation, we compared all the inferred and original SSR, and we performed a critical analysis on the spectral characteristics of earthquake site response recovered from noise measurements.