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When 1D response analysis fails: application of Earthquake HVSR in Site-Specific Amplification Estimation

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Ground response analyses (GRA) model the vertical propagation of SH waves through flat-layered media (1DSH) and are widely carried out to evaluate local site effects in practice. Horizontal-to-vertical spectral ratio (HVSR) technique is a cost-effective approach to extract certain site-specific information, e.g., site resonant frequency, but HVSR values cannot be directly used to approximate the level of S-wave amplification. Motivated by the work of Kawase et al. (2019), we propose a procedure to correct earthquake HVSR amplitude for direct amplification estimation. The empirical correction, in essence, compensates HVSR by generic vertical amplifications grouped by vertical fundamental resonant frequency (f_{0v}) and 30 m average shear-wave velocity (V_{s30}) via k-mean clustering. In this investigation, we evaluate the effectiveness of the corrected HVSR in approximating observed amplification in comparison with 1DSH modelling. To the end, we select a total of 90 KiK-net surface-downhole recording sites which are found to have no velocity contrasts below downhole sensor and thus of which surface-to-borehole spectral ratio (SBSR) can be taken as its empirical transfer function (ETF). 1DSH-based theoretical transfer function (TFF) is computed in the linear domain considering the uncertainty in V_s profile through randomization. Five goodness-of-fit metrics are adopted to gauge the closeness between observed (ETF) and predicted (i.e., TFF and corrected HVSR) amplifications in both amplitude and spectral shape. The major finding of this study is that the empirical correction procedure to HVSR is highly effective, and the corrected HVSR has a “good match” in both spectral shape (Pearson’s $r > 0.6$) and amplitude (Index of agreement $d > 0.6$) at 74% of the investigated sites, as opposed to 17% for 1DSH modelling. In addition, the HVSR-based empirical correction does not need a site model and thus has great potentials in site-specific seismic hazard assessments.