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A workflow to discern 1D and 2D ground resonances with single-station microtremor measurements

Giulia Sgattoni and Silvia Castellaro
Alma Mater Studiorum Università di Bologna, Dipartimento di Fisica e Astronomia, Bologna, Italy

Measuring ground resonances is of great importance for seismic site amplification studies. The task is usually addressed with the common H/V (horizontal to vertical spectral ratio) approach, which is widely used for both microzonation studies and stratigraphic imaging. Peaks on the H/V function are used to identify ground resonance frequencies, usually assuming 1D site conditions, i.e. with plane-parallel stratigraphy. In the simple case of a horizontal soft layer overlying a bedrock, 1D resonance is linked to the local bedrock depth (as a function of the shear wave velocity of the sediment layer). Therefore, when the 1D approximation holds, spatial variations of the resonance frequency reflect changes of bedrock depth (when lateral homogeneity of the sediment cover can be assumed). However, at sites with non-plane subsurface geometries, more complex resonance patterns may develop, such as 2D resonance patterns that typically occur within sediment-filled valleys. In this case, 2D resonance involves simultaneous vibration of the whole sedimentary infill at the same frequency, which may lead to large seismic amplification. 2D ground resonances can no longer be linked to the local depth-to-bedrock directly below the measurement site, but depend on the whole valley geometry and mechanic properties. Distinguishing between the 1D and 2D nature of a site is mandatory to avoid wrong stratigraphic and dynamic interpretations, which is in turn extremely relevant for seismic site response assessment.

We investigated the problem in the Bolzano sedimentary basin (Northern Italy), which lies at the intersection between three valleys, using a single-station microtremor approach, the same usually applied for H/V surveys. We observed that the footprints of 1D and 2D resonances reside in different behaviors along the three components of motion. This is because, while the dynamic behavior of a 1D-site is the same along all horizontal directions, 2D resonances differ along the longitudinal and transversal directions of the resonating body, e.g. parallel and perpendicular to the valley axis. In addition, 2D resonance modes involve also a vertical component. This implies that the H/V method, by mixing the information along the three components, is not suitable to detect 2D resonances, that can be acknowledged only by looking at the individual spectral components and not at the H/V curves alone.

By analyzing several hundred single-station microtremor measurements, we identified a list of frequency and amplitude features that characterize 1D and 2D resonances on individual spectral components of motion and on H/V ratios, on a single measurement and on several measurements

acquired along profiles across the investigated valleys. We identified valleys characterized by 1D-only, 1D+2D and 2D-only resonance patterns and we propose a workflow scheme to conduct experimental measurements and data analysis in order to directly assess the 1D or 2D resonance nature of a site with a single-station approach, rather than evaluating this indirectly with numerical modelling.