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A comparison of site response techniques using earthquake data analysis and ambient seismic noise in large urban areas of Santiago de Chile

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Situated in an active tectonic region, the densely populated urban area of Santiago de Chile with more than six million inhabitants suffers significant seismic risk. Due to the dimension of the investigated area, the application of invasive procedures for a detailed analysis would lead to disproportionate costs. Therefore, other approaches (H/V method both for earthquakes (EHV) and for ambient seismic noise data (NHV) as well as the classical spectral ratio (CSR) technique) that allow to derive at least a rough classification of the soil response have to be used. The results are compared in terms of predominant frequencies and amplitudes. Therefore, our contribution to the mitigation of earthquake risk includes a microzonation study using ambient seismic noise as well as H/V and CSR techniques of earthquakes at characteristic sites to validate the results.

In order to estimate the site response of several characteristic areas inside the city, a network composed of eight seismological stations was installed for recording earthquake signals over a period of ten weeks. 40 events with good signal-to-noise ratio have been recorded allowing a detailed analysis to both P- and S-waves. A large variability of the site response in the investigated area with respect to local geology is observed. In some parts of the basin, irrespective of the thickness of the sedimentary cover, the peak ground velocity is largely amplified with respect to the reference station installed on rock, and also the duration is increased on average by a factor of two. EHV and CSR methods usually provide site responses with similar shapes and amplifications occuring over large frequency ranges when only the S-wave part of the seismogram is used; the P-wave part is found to provide consistent results only in some cases. However, the spectral analysis of earthquake data shows that significant amplification of ground motion may also occur at frequencies higher than the fundamental one even when thick sediments are present. Using the H/V ratio applied to ambient seismic noise at the seismological stations, for most cases, we obtained an estimate of the fundamental resonance frequencies consistent with that from earthquakes. Furthermore, also NHV shapes were found to be in good agreement with those results. Nonetheless, H/V amplitudes obtained from noise are always smaller than those from earthquake data. The difference can be as much as a factor of two.

Additionally, measurements of seismic noise at 150 sites have been carried out in Santiago de Chile to determine the fundamental frequency of the sites. It can be seen that the spatial variation in the thickness of the sedimentary cover, known from previous gravimetric investigations, is roughly retrieved using the fundamental resonance frequency estimated from the peak in the H/V ratios of ambient noise. Using an inversion procedure, the S-wave velocity profile below the sites can be derived under the constraint of the thickness of the sediments. These profiles can then be used in turn to derive site responses and to obtain a 3D structure of the basin.