Thesis

Contribution of seismic and ambient noise records for site-specific seismic hazard assessment in low to moderate seismicity area

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Summary

Site effects can greatly increase both the duration and the amplitude of the seismic solicitation imposed on structures. 2D-3D site effects induce broadband amplifications that cannot be simulated up to high frequency (>2-4 Hz) due to the limited resolution of the geological, geophysical and/or geotechnical information. Empirical site effect assessment is therefore essential for reliable observations of this complex phenomenon up to high frequency. However, such assessments often require good quality records from many earthquakes that cannot be rapidly obtained in low seismicity areas.

This work presents a comparative analysis of these empirical evaluations on two very different sites, the first in a moderate seismicity context (Provence, France) and the second in a very active context (Kefalonia, Greece). For the Provençal site, nearly 500 earthquakes were recorded in only 2½ years thanks to the use of velocimeters. The site attenuation parameter κ_0 could thus be measured both on the acceleration (κ_{0_AS}) and displacement (κ_{0_DS}) spectra. Our results show that the measurement of κ_0 is relatively reliable on rock sites only, mainly due to the too great disturbance by the amplification for sedimentary sites, even for those that are quite stiff. The standard spectral ratio (SSR) approach provides the relative site effects from the numerous weak motion recordings available at sites located in Provence and Kefalonia. The results show a strong epistemic variability due to the lighting induced by the position of the seismic source with respect to the basin. Thus, while a reliable site response estimation is possible from only a few events for 1D geometries, it requires much more earthquakes evenly distributed around the site when the geometry is 2D-3D. The mean SSR results are then compared with those obtained from methods using the ambient noise. As expected, the H/V spectral ratio approach (HVSR) provides only the fundamental frequency for some sites. Conversely, SSR applied to ambient noise (SSRn) shows very similar results to the SSR method up to high frequency, provided that the reference site is taken in the sedimentary basin. Approaches using the noise correlation (coherence and ANIRF) reveal that the transfer function relative to a rock reference site can be estimated at least up to low frequency (<4 Hz). Methods using ambient noise are promising for a rapid evaluation of the site response and its spatial variability (microzoning), even when seismicity is low. Empirical site effects methods are therefore applicable everywhere. They provide an essential complement to numerical approaches, which remain inevitable when the coverage of available earthquakes is not homogeneous or when soils are likely to present non-linear behaviors.

These results led us to propose a methodology for the evaluation of the site-specific seismic hazard, which consists of three main stages: (i) adjustment to the rock reference site of the

ground motion prediction equations (GMPEs) using, among others, κ_{0_DS}; (ii) Reliable evaluation of the SSR transfer function between at least one site in the basin and the reference site (for which the GMPEs were adjusted); (iii) carrying out this assessment from the ANIRF in the less seismically active regions and/or extension to the entire study area with the SSRn. This methodology allows a much better consideration of the site effects (especially 2D-3D) and a significant reduction of the uncertainties in the evaluations of the site-specific seismic hazard. It only required, simultaneous recording of earthquakes on at least two sites equipped with sensible velocimeters, and to carrying out temporary campaign of ambient noise measurements, if necessary.

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