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Calculating Basin Response by Numerical Modeling of Wave Propagation - The Taipei Basin Example

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Calculating low frequency response of sedimentary basins and the understanding of the associated wave effects is an important issue because structures with large response periods such as bridges and tall buildings are sensitive to the low frequency range (f < 1 Hz). We calculate low frequency basin response for the Taipei basin by numerical simulations of wave propagation and compare the modeling results with findings from observed data.

During the 20th century four earthquakes caused severe damage in Taipei in northern Taiwan (April 15, 1909; November 15, 1986; September 11, 1999; March 31, 2002). The city is located on a sedimentary basin, which can be divided in a deep western and a shallow eastern part. The Taipei area is covered with a dense strong motion network which is operated in the frame of the TSMIP (Taiwan Strong Motion Instrumentation Program). Analysis of recorded data showed that shallow earthquakes cause large amplifications at low frequencies. Furthermore, a clear earthquake azimuth dependence of spectral amplifications was observed. We apply 3D finite difference simulations of an incident S-wave front on the basin for different azimuths and incidence angles corresponding to deep and shallow earthquakes. We perform the simulations for the 3D basin structure and a homogeneous model that reflects hard rock conditions. From the modeling results we calculate frequency dependent spectral amplification ratios. Because of the assumed planar wave front incidence source and path effects are excluded and the calculated amplification effects describe the relative influence of the basin structure only. These modeled amplification factors could be superimposed on existing standard hard rock attenuation relationship in order to calculate absolute ground motion parameters within the basin.

Our modeling results reveal the generation of strong surface waves at the basin edges for shallow earthquakes. Consequently, shallow earthquakes produce larger spectral amplifications within the basin compared to deep earthquakes. The dominant frequencies of spectral amplifications vary between 0.3 Hz in the deepest part of the basin to 0.6 Hz in the eastern shallow part of the basin. This frequency behavior was also found from analysis of observed data. Furthermore, modeling results show, like the observations, strong earthquake azimuth dependence of spectral ratios. We compare also the modeled spectral amplification for 0.5 Hz with the results of a microtremor survey. Modeling and observations show the same areas of large amplifications and similar absolute maximum amplification factors of about 5 - 10.

Our study showed that modeling explains the observed ground motion peculiarities. We found also a good quantitative agreement of the simulated and observed amplification factors at a frequency of 0.5 Hz. In the case of the Taipei basin we showed that for a detailed knowledge of the subsurface structure, numerical simulation of wave propagation of an incident S-wave front is capable to reproduce low frequency basin response. Consequently, the method can be a valuable tool for sedimentary basins with a well known subsurface structure but a small database of observations because of low seismicity or short observation times.