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On the Horizontal-to-Vertical Spectral Ratio in Sedimentary Basins

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Abstract The horizontal-to-vertical spectral ratio (HVSR) has been used by many researchers to characterize local conditions in terms of the dynamic response of the soil. One of its variants is that proposed by Nakamura (1989) in which records of microtremors are used. Usually, the analysis is aimed to obtain the predominant period of the site under study. In this work we explore what can be achieved by using this method. We study the response of different configurations under incident waves coming from an explosive source using the indirect boundary element method (IBEM). We investigate two cases: low- and high-velocity contrast, holding constant the physical properties inside the basin and changing only the properties of the bedrock. Then, we compute the seismic response using the horizontal sediment-to-bedrock spectral ratio (SBSR) at various locations on the free surface of the basins, and compare it with the one calculated by the HVSR at the same locations. The comparison shows that, in general, the predominant period computed with the HVSR is not the same as that obtained by the SBSR in all the locations. On the other hand, the HVSR approximation can reasonably well predict the fundamental local frequencies when the impedance contrast between the basin and the bedrock is low. However, HVSR cannot be used in sedimentary basins having a high impedance contrast with respect to the bedrock below.

Introduction

As it is well known, the local geological conditions can produce important changes in the ground motion during earthquakes. One way of estimating these local effects is by means of empirical methods that are based on the analysis and treatment of records (see Aki, 1988, for an extensive review). One popular technique is the one presented by Nakamura (1989), which uses microtremors to estimate the amplification for the horizontal motion of the surface layers during earthquakes. This approach has been used by a great number of seismologists and engineers in the last few years with the aim of characterizing the seismic hazard in a small scale and of providing detailed information for seismic microzonation in urban areas. In principle, this procedure has several advantages: only a seismic station with three components is needed, and it is not necessary to wait for the occurrence of an earthquake as microtremors provide the input motion. In some cases, the analysis with the horizontal-to-vertical spectral ratio (HVSR) provides a distribution of predominant periods of the zone under study (see, e.g., Konno and Ohmachi, 1998); that is, the periods with maximum amplification observed on the spectra of each site of the zone. Nevertheless, this technique is not at all reliable, and further work is necessary to calibrate the method to assess the limits of validity.

The purpose of this article is focused in this direction: we did some numerical experiments to determine how far we could go using this method in sedimentary basins. First, we show briefly Nakamura's technique and the underlying hypothesis. Subsequently, we present the response of sedimentary basins under incident waves coming from an explosive source using the indirect boundary element method (IBEM). After this, we compute the horizontal sediment-to-bedrock spectral ratio (SBSR) for various locations on the basins surface and compare it with the one calculated using the HVSR at the same locations.

Nakamura's Technique

Nakamura (1989) considered that spectral amplification of a surface layer could be obtained by evaluating the HVSR of the microtremors recorded at the site. This technique implies (Lermo and Chávez-García, 1994; Dravinski *et al.,* 1996) that microtremors are primarily composed of Rayleigh waves, produced by local sources, which propagate in a surface layer over a half-space; also, considering that the motion at the interface of the surface layer and half-space is not affected by the source effect, and that the horizontal and vertical motion at this interface are approximately equal, it is found that the site effect $S(f)$ can be computed by the spectral ratio of horizontal versus vertical components of the surface motion at the same place, that is,