Bulletin of the Seismological Society of America, 91, 6, pp. 1526–1536, December 2001

Comparison of Site Response Characteristics Inferred from Microtremors and Earthquake Shear Waves

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Abstract We investigated the validity of seismic site response characteristics estimated from microtremors by comparing them with those of earthquake motions. For this purpose we observed microtremors as well as earthquake motions using large (5-km diameter) and small (0.5-km diameter) arrays deployed on soft sediments. Specifically, we examined four estimates from microtremors: relative site amplification factors to incident shear waves, site amplification factors by the Nakamura method, resonance frequency in horizontal-to-vertical spectral ratios, and horizontal-to-vertical spectral ratios. As a result of the comparisons, we obtained the following conclusions. The relative amplification factors can be inferred from horizontal-component ratios of microtremors to a reference site within a small area of several hundred meters. The horizontal-to-vertical spectral ratios inferred by the Nakamura method partly reflect site amplification factors, but do not agree with site amplification factors. A sharp-peak frequency in the horizontal-to-vertical spectral ratios is possibly the resonance frequency. The horizontal-to-vertical spectral ratios of microtremors either agree with those of earthquake motions at some array sites or are slightly smaller at the other sites.

Introduction

Since the pioneer work by Kanai and Tanaka (1954), microtremors have been studied as a tool to estimate seismic site responses because microtremor measurements are much easier than earthquake observations and are suitable for inference of spatial variability of seismic site responses (i.e., microzonation). A main subject in the early stage was to estimate the resonant frequency (Kanai *et al.*, 1954; Katz, 1976; Ohta *et al.*, 1978; Field *et al.*, 1990). However, there are two different conclusions about the relationship of microtremor predominant frequency with local site conditions: (1) the microtremor predominant frequency is controlled by geological site conditions, (Kanai and Tanaka, 1961; Kubotera and Otsuka, 1970), and (2) it is primarily controlled by the microtremor source and propagation path (Udiwadia and Trifunac, 1973). These inconsistent conclusions suggest that the effects on microtremors of geological site conditions, microtremor source, and propagation path vary with observation sites. Therefore, the effects of the microtremor source and path must be removed to obtain reliable estimates of seismic site response characteristics.

There are two estimates of seismic site responses from which the effects of the microtremor source and path are to be removed. The first is from horizontal-component spectral ratios relative to a reference site (hereafter referred to as HH ratios) (e.g., Seo and Samano, 1993). The second is from the spectral ratios of horizontal components relative to the vertical components (hereafter referred to as HV ratios) at a site (Nakamura, 1988). Although these estimates are free from microtremor source and path effects, problems still remain in their use. Next we describe them briefly.

There are two problems for microtremor HH ratios. The first is whether they coincide with the relative site amplification factors to seismic shear-wave incidence. The second is a problem regarding areas over which the microtremor HH ratios should be used. Because microtremors are generated by human activities, especially in urban and suburban regions, the intensity of microtremor source seems to significantly vary from place to place. However, the validity of microtremor HH ratios is based on an assumption that the intensity of microtremor source (or incoming microtremors) is the same between sites. Thus, the second problem is over how large an area incoming microtremors are the same.

Nakamura (1988) proposed a method of inferring site amplification factors to incident seismic shear waves using microtremor HV ratios at a single site. This method is easily applied and directly estimates the site amplification factors without a reference site, and much research has been done to investigate the validity by observation and in theory. Summarizing the results of the research, some say that the microtremor HV ratios coincide with amplification factors of near-surface structures to incident shear waves (Lermo and Chavez-Garcia, 1993; Chavez-Garcia *et al.*, 1996; Seekins