A method for simulating strong vertical motions
Application to the 1995 January 17 Hyogo-ken Nanbu Earthquake (M_{JMA}=7.2)

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Introduction

The stochastic simulation method is a useful tool to compute strong ground motions (Boore, 1983). However, it generates only horizontal-component (actually, the average of two horizontal components) earthquake motions. We have observed that although microtremor HV ratios are smaller than earthquake motion HV ratios, their spectral shapes are similar, and suggested that the difference between the two ratios is controlled by local geological conditions (Zhao *et al.,* 2000). This implies that earthquake motion HV ratios can be obtained from microtremor HV ratios using a correction factor common for geologically similar sites.

In this paper, we first show that the HV ratios of earthquake motions can be derived from microtremors (Horike *et al.,* 2001). Then, we simulate vertical earthquake motions using the microtremor HV ratios. The result suggest that the stochastic simulation method can extended to include computation of vertical earthquake motions as well horizontal using microtremor HV ratios.

Comparison of Microtremors and Earthquake Motions

Figure 1 shows the locations of microtremor and earthquake motion observation sites in the Osaka basin. The basement rock ranges from Permian to Jurassic sedimentary rock (Tamba group) in the north of the basin and Cretaceous granitic rock in the south. Microtremors were observation atpoints close to the earthquake observation sites (less than 10 m) by an electro-magnetic-type velocity sensor with a flat response in the frequency range of 0.1 Hz to 10 Hz.

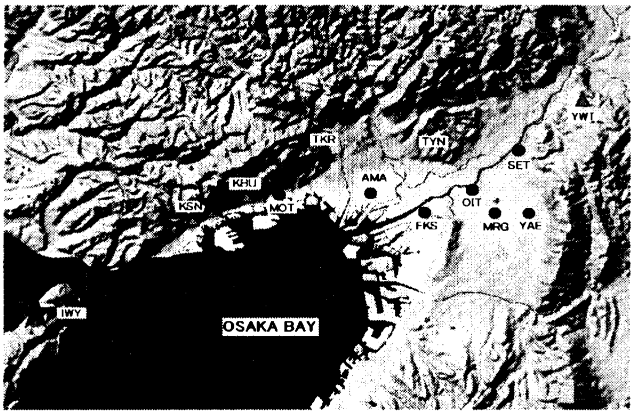

Figure 1. Locations of sites and epicenters of point sources. Squares are rock sites, triangles are hard-sediment sites, and Circles are soft-sediment sites. Stars denote point sources.

Figure 2 shows typical examples of the HV spectral ratios of microtremors and earthquake motions at rock, hard-sediment, and soft-sediment sites. In contrast to a small variation of the HV ratios with respect to frequencies at rock site, we can clearly observe a large variation of the HV ratios at hard and soft sediment sites. Since the width between the standard deviations of the earthquake-motion HV spectral ratio is narrow, we know that the earthquake-motion HV spectral ratios are stable estimates, irrespective of earthquake events, suggesting that the vertical component of earthquake motions is primarily generated by local site conditions.

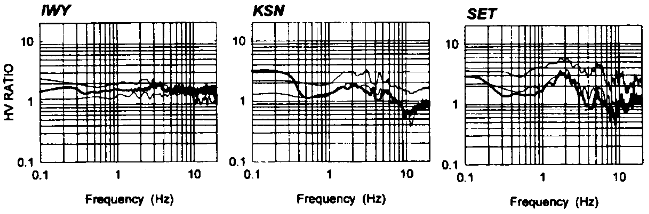

Figure 2. Examples of HV ratios for three geologically representative sites.

Correction Factor

We examine whether geological conditions are responsible for the correction factor. The correction factor *CF* is computed by the equation derived from the least square fitting. We use the microtremor and the earthquake-motion HV ratios in the frequency band 0.5 Hz to 10 Hz for this purpose. At all the sites the corrected microtremor HV ratios are similar to the earthquake motion, indicating that the correction factors are estimated appropriately. The correction factors for soft-sediment sites, range between 1.7 and 2.1 and are large compared with those at rock and hard-sediment sites. These results indicate that a correction factor of about 2 is suitable for soft sediment sites and a correction factor of about 1.2 is suitable for the rock and the hard-sediment sites. However, it should be mentioned that these values should be limited within the Osaka basin.

Key words: Stochastic simulation method, Strong vertical motions, Microtremor HV ratios, Osaka basin, Correction factor
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Simulation of Vertical Earthquake Motions

We simulated vertical ground accelerations at sites FKS and MRG for the Kobe earthquake using the corrected microtremor HV ratios (Figure 3). Strong horizontal ground accelerations were calculated using the stochastic simulation method in conjecture with the ω^{-2} source spectra (Boore, 1983). Vertical accelerations were computed by the same method except for using modified source spectra where the ω^{-2} source spectra are divided by the corrected microtremor HV ratios. It should be mentioned that the modified source spectra are required only for the convenience of simulating vertical component earthquake motions by the stochastic simulation method.

The source model of the Kobe earthquake is composed of three asperities (Kamae and Irikura, 1998). We replaced them with three point sources, which are located at the center of the asperities. Their epicenters are shown in Figure 1. We used 2 times the seismic moment and 2.5 times the stress drop as shown in Table 1. The radiation coefficients were assumed to be 0.64. Subsurface structure models of sediments at the three sites were derived from results of the reflection and the microtremor array surveys.

The correction factor of 2.0 is used for both sites. Simulated horizontal and vertical accelerations are well reproduced in peak acceleration and duration in the S wave portion. Also, rich high-frequency contents in vertical motions are well reproduced. As can be seen in the recorded vertical component, the contribution from P waves and P coda is very large. However, it should be mentioned that, as a matter of course, these vertical motions cannot be reproduced because the stochastic simulation method does not incorporate P wave radiation from the sources. Figure 4 shows the spectral ratios of recorded motions to simulated motions at sites FKS and MRG.

Conclusion

We examined the possibility for the simulation of strong vertical motions using microtremor HV ratios. Introducing the correction factor to compensate for the difference between the microtremor and the earthquake motion HV ratios, we successfully reproduced strong vertical ground motions during the Kobe earthquake at the two sites over thick alluvial deposits by the stochastic simulation method.

Acknowledgements

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References

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Table 1 Source Parameters for Three Point Sources

	Moment (Nm)	*Stress drop (MPa)*	*Fmax (Hz)*
Point source 1	$2*10^{19}$	21.5	12
Point source 2	$6.8*10^{18}$	40.8	12
Point source 3	$3.6*10^{18}$	21.5	12

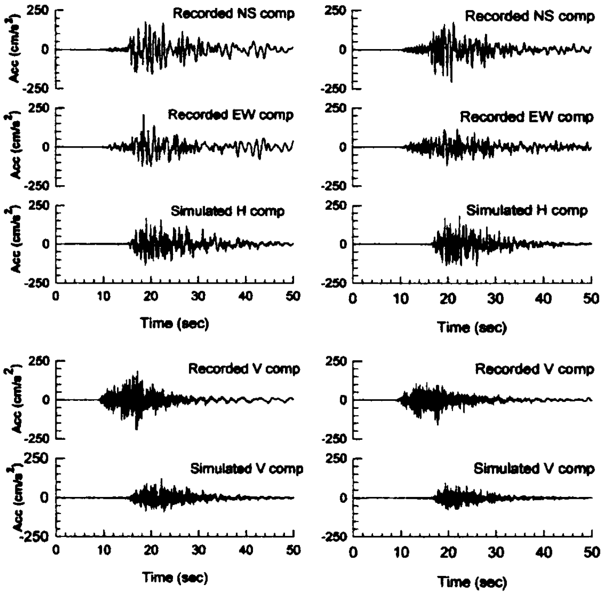

Figure 3. Simulated and recorded ground motions at sites FKS (left side) and MRG (right side) for the Kobe earthquake.

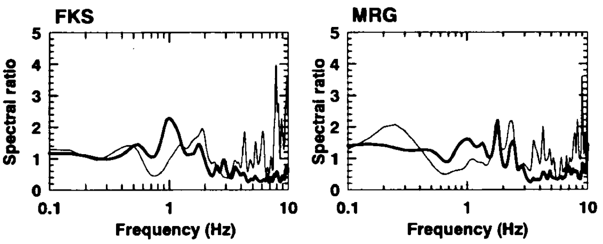

Figure 4. Spectral ratios for horizontal component (thick line) and for vertical component (thin line) between simulated and records for the Kobe earthquake.