I-B 208 SITE CHARACTERIZATION BY HORIZONTAL-TO-VERTICAL SPECTRAL RATIO

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INTRODUCTION: In order to evaluate site amplification characteristics during earthquakes, Nakamura[1] proposed a method to estimate the horizontal and vertical Fourier spectral ratio of microtremor. The method was extensively used in Japan and for some other countries. Most of the studies supported the validity of the method for microtremor. The amplitude ratio as defined by Nakamura is applied for intense body-wave part of the earthquake records and found to be stable irrespective of magnitude, location and source of earthquake events.

In this study, a new attenuation model proposed by Molas and Yamazaki[2] is used where site amplification is considered by assigning a station coeficient for each JMA station. This was made possible due to the recording of several earthquake events at each station.This paper is aimed to find some validation in the stability of the spectral amplitude ratio of earthquake ground motion using JMA records compiled by Molas and Yamazaki[2].

DATA: The data set used in this study consists of 2,166 earthquake acceleration records from 387 events. These time histories are recorded by JMA at 76 free field sites from August 1, 1988 to December 31, 1993. The records consist of mostly far-field ones. Records with peak ground accelerations (PGA) less than 1.0 cm/s2 in one horizontal component are omitted. Events whose focal depths are zero and greater than 200 km are also excluded from the analysis.

The velocity response spectrum, $S_V(\zeta,T)$, used in this study is defined as the maximum response of a two percent damped single-degree-of-freedom oscillator of varying structural period, T. The responses are calculated by the Newmark's direct integration method from the acceleration time histories. The velocity response spectrum for the two horizontal components are calculated and larger of the two in each period, $S_V{}^H(\zeta,T)$, is used in statistical analysis. The vertical velocity response spectrum, $S_V{}^V(\zeta,T)$ is also calculated. Sixteen structural periods from 0.05s to 2s are selected and a regression analysis is performed separately for each structural period.

STABILITY OF FOURIER SPECTRAL RATIO: Among the 76 JMA stations, only one station is selected for demonstration. For each station, ten large accelerograms are selected for the estimation of horizontal-to-vertical Fourier spectrum ratio. The amplitude ratios in two horizontal directions, i.e., $AR_{NS}(T)$ and $AR_{EW}(T)$, are estimated using the following equation:

$$AR_{NS}(T)=\frac{F_{NS}(T)}{F_{UD}(T)} \qquad AR_{EW}(T)=\frac{F_{EW}(T)}{F_{UD}(T)} \tag{1}$$

where $F_{NS}(T)$, $F_{EW}(T)$ and $F_{UD}(T)$ are the Fourier amplitude spectra in the NS, in the EW and in the UD directions, respectively.

Figure 1 shows the Fourier spectra of NS and UD components for the JMA station at Hachinohe. Each earthquake record used for this study is at least of 20s length. Although the amplitude of the Fourier spectra of the events fluctuate, the shapes of the spectra look rather similar. Figure 1 also shows the Fourier spectral ratios of the earthquake records for NS and EW components. Although Fourier spectra of earthquake events show wide variability in their amplitudes, the amplitude ratios are stable and show clear peaks. The discussion related to the stability of horizontal-to-vertical ratio of Fourier spectra on the ground surface is provided later.

ATTENUATION MODEL: The attenuation of the response spectrum is modelled using the attenuation model for the peak ground acceleration and velocity as proposed by Molas and Yamazaki[2]. The attenuation

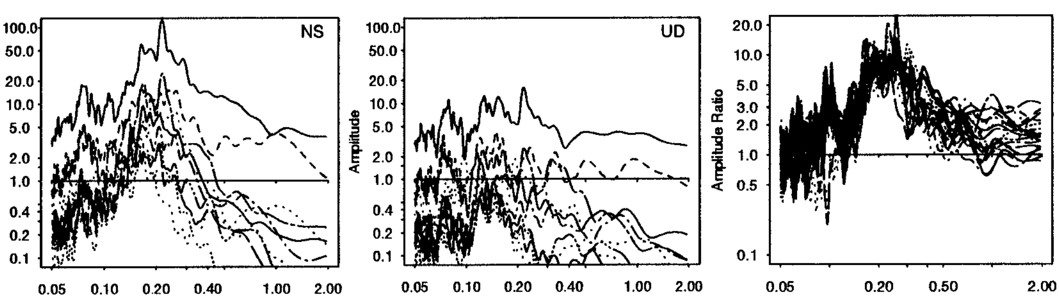

Fig. 1 Horizontal, vertical Fourier spectra and amplitude ratio (NS and EW) of earthquake events at JMA Hachinohe station

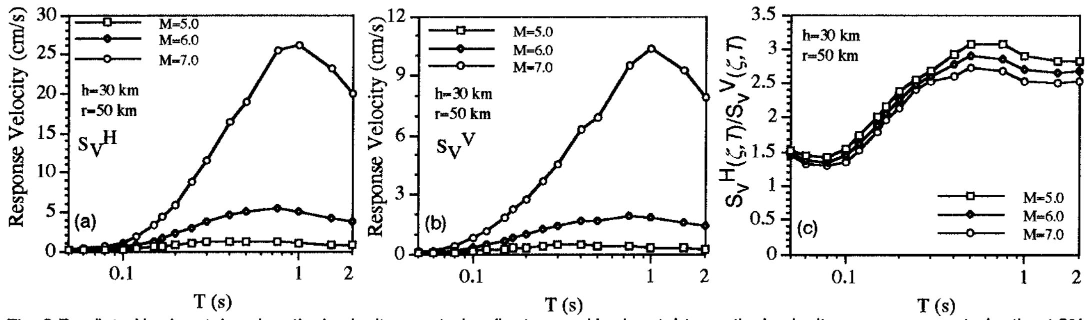

Fig. 2 Predicted horizontal and vertical velocity spectral ordinates, and horizontal-to-vertical velocity response spectral ratio at 2% damping and c_i=0.0

model considers the attenuation of seismic waves in a continuous medium with a geometric spreading term, an elastic attenuation term, a depth factor and a local site factor as shown by

$$\log y(T) = b_0(T)+b_1(T)M+b_2(T)r+b_3(T)\log r+b_4(T)h+\sum_{i=1}^{N} c_i(T)S_i+\sigma P \quad (2)$$

where y(T) is the response spectrum at period T; M is the JMA magnitude, r is the shortest distance in kilometer between the source and the recording station, bi(T)'s are the coefficients to be determined and s is the standard deviation of log y(T) with P=0 for 50-percentiles and P=1 for 84-percentiles.

Since regression analysis is performed for each structural period independently, the index (T) indicating the frequency dependence of each variable has been dropped from the equations, for clarity. It is thus understood that the regression procedure is performed separately for each structural period under consideration.

The attenuation relation of horizontal and vertical components of $S_V(\zeta,T)$ derived here are used to explain the reason behind the stability of horizontal-to-vertical Fourier spectral ratio of different earthquake records for each station. For this purpose following equation is followed.

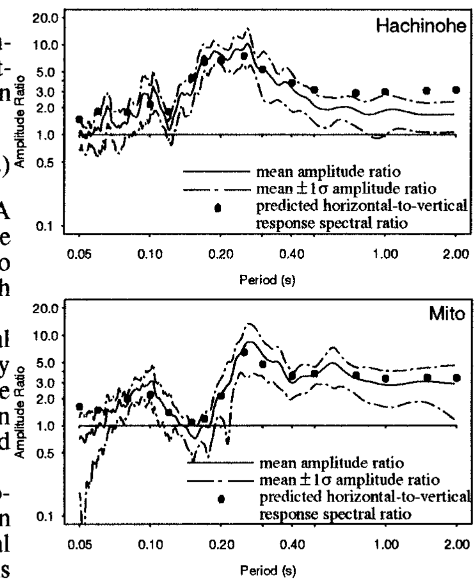

Fig. 3 Comparison between predicted horizontal-to-vertical velocity response spectral ratio at 2% damping, mean amplitude ratio and mean plus or minus one standard deviation for two JMA stations

$$\log\frac{S_V^H(\zeta,T)}{S_V^V(\zeta,T)} = (b_0^H-b_0^V)+(b_1^H-b_1^V)M+(b_2^H-b_2^V)r$$
$$+(b_4^H-b_4^V)h+(c_i^H-c_i^V)+(\sigma^H-\sigma^V)P \quad (3)$$

The methodology used for the analysis of the data set is based on Molas and Yamazaki[2].

ANALYSIS AND RESULTS: Figures 2a and 2b show estimated horizontal and vertical velocity response spectra for a given depth and shortest distance with changes in magnitude. The structural period where the peak of the response curves occurs increases as the magnitude increases. Figure 2c shows the velocity response spectral ratio for a given depth and shortest distance with changes in magnitude. In the very short-period range (less than 0.1s), horizontal-to-vertical ratio is almost constant; in short-period range (0.1s to 0.5s), the ratio increases linearly with period; in the intermediate to long-period range (0.5s to 2s), the ratio becomes almost constant.

Figure 3 compares the predicted spectral ratio with the mean value and plus or minus one standard deviation of observed amplitude ratio at two JMA stations. The comparison reveals that predicted value of velocity response spectral ratio at low damping value produces similar amplification as the observed horizontal-to-vertical ratio of Fourier amplitude.

CONCLUSION: The horizontal and vertical velocity response spectral values are dependent on magnitude and in some extent to distance and depth. It is also observed that horizontal-to-vertical ratio of velocity response spectrum is independent of magnitude, distance and depth and introducing station coefficient factors in this relation, yields values comparable to horizontal-to-vertical ratio of Fourier spectrum at specific sites. So, this amplitude ratio method for earthquake ground motion, will be useful for site-specific hazard assessments.

REFERENCES:

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2. G. L. Molas and F. Yamazaki, ' Attenuation of earthquake ground motion in Japan including deep focus events', Bull. seism. soc. Am. 85, 1343-1358 (1995a).