SIMULTANEOUS SIMULATION OF DISPERSION CURVES AND H/V SPECTRA

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Summary Subsurface modelling beneath an earthquake observation station is necessary to study incident waves from observed earthquake records. By a case study, we will show an advantage of simultaneous simulation of surface wave dispersion curves and H/V spectra obtained by micro-tremor measurement for subsurface modelling; shallower part of the subsurface model can be evaluated by stable surface wave dispersion curves and deeper part of the model can be constrained by less informative peak and trough frequencies of H/V spectra.

INTRODUCTION

Once strong earthquake ground motion is captured, incident waves at bedrock raise interest for a study of earthquake characteristics and future structural design. We need a subsurface model to decompose earthquake ground motion on the ground into incident waves. Unless there situates a vertical array, we will deduce it from micro-tremor measurement on the ground at the cheapest. We can deduce surface wave dispersion curves by micro-tremor array observation and simulate them for subsurface models and also we can use H/V spectrum to obtain rough image of subsurface model such as base rock depth; however, simultaneous use of them has been scarcely reported. With a case study, we will demonstrate an advantage of simultaneous simulation where array size is only valid for higher frequencies; shallower part of the subsurface model is evaluated by stable surface wave dispersion curves and deeper part of the model is constrained by less informative peak and trough frequencies of H/V spectra.

RAYLEIGH WAVE DISPERSION CURVES AND H/V SPECTRA

A test site is selected at one of the Kik-net [1] observation stations in the western part of Japan, where a vertical array up to the depth of 100m is situated and PS logging data is available, so that we can study a subsurface model deduced by micro-tremor measurement referencing to the PS data and will be able to verify it with transfer function of horizontal components. We constructed regular-triangular shaped micro-tremor array of three different circumscribed radii of 3m, 10m, and 20m, with a three-component portable seismograph at each array point, which enables us to evaluate H/V spectrum at the same time. Micro-tremor was measured for 20 minutes with 200Hz sampling in acceleration, low pass filtered at 50Hz.
The SPAC method [2] is used on vertical components of array data to evaluate Rayleigh wave phase velocity dispersion curves shown in Fig. 1a. Symbols representing different array radii lie successively on a line, which can be assumed as Rayleigh wave fundamental mode dispersion curve. H/V spectrum [3] is evaluated by Hv type transfer function algorithm for stationary signal shown in Eq. 1, which is considered optimal for noise contaminated input and output, in this case vertical component as input and horizontal component as output,

$$\begin{bmatrix} G_{AA} & G_{AB} \\ G_{BA} & G_{BB} \end{bmatrix} \begin{Bmatrix} -H_V \\ 1 \end{Bmatrix} = \varepsilon \begin{Bmatrix} -H_V \\ 1 \end{Bmatrix} \quad (1),$$

where G_{AA} and G_{BB} are auto power spectrum densities, G_{AB} and G_{BA} are cross power spectrum densities, and H_v the transfer function is the one for the smallest eigenvalue of ε. In Fig. 2a, averaged H/V spectrum over azimuth with 5 degree interval is shown with $H_1 = G_{AB} / G_{AA}$ and $H_2 = G_{BB} / G_{BA}$ exhibiting clear peaks compared to H_1.

SIMULTANEOUS SIMULATION FOR SUBSURFACE MODEL

The generalized transfer and reflection matrix method [4] is used to simulate Rayleigh wave dispersion curves and H/V spectra by H/V ratio of Rayleigh wave trajectory. We have formulated a transcendental equation to obtain Rayleigh poles by imposing a wave existence condition without an internal source. PS logging data and a former proposed subsurface model by Higashi and Abe [5] are compared in Fig. 3a, the latter has base rock below 84m referencing to reflection survey around the station. A comparison of dispersion curves and H/V spectra for these models supports the idea of base rock underneath; however, the velocity structure of Higashi-Abe model looks stiffer between 4Hz and 10Hz. The Higashi-Abe model can produce a peak of H/V ratio of Rayleigh wave trajectory around 2Hz, which is similar property seen in H/V spectrum though with some anbiguity.
In order to simulate the dispersion curves based on the Higashi-Abe model, shear wave velocities should be lowered. With trial and error basis, we have lowered shear wave velocities of the third and forth layers by about 30% (model A) to simulate the dispersion curves shown in Fig. 1b; however, a peak frequency of H/V ratio is also lowered and separated from the H/V spectrum as shown in Fig. 2b. Since we found the dispersion curve between 3Hz and 10Hz was controlled by the upper four layers, we tried to simulate H/V peak frequency by increasing shear wave velocity of the fifth layer as shown by model B in Fig. 3b; nonetheless, any higher shear wave velocities cannot bring the peak

frequency higher. Then we tried to get the interface between the forth and fifth layers shallower (model C) and succeeded to simulate both of the dispersion curves and a peak frequency of the H/V spectrum at the same time. This case study shows that unless we can situate a large size micro-tremor array, the surface wave dispersion curves can provide information for shallower part of the subsurface model only, even if the data is good and stable. H/V spectra can supplement the dispersion curves with peak and trough frequencies, though the data is less informative.

CONCLUSIONS

We have shown an advantage of simultaneous simulation of Rayleigh wave dispersion curves and H/V spectra for subsurface modelling with detailed shallower part and rough estimate of the deeper part, which can be done as the cheapest unless we have a vertical array data. The subsurface model will be verified by the vertical array transfer function.

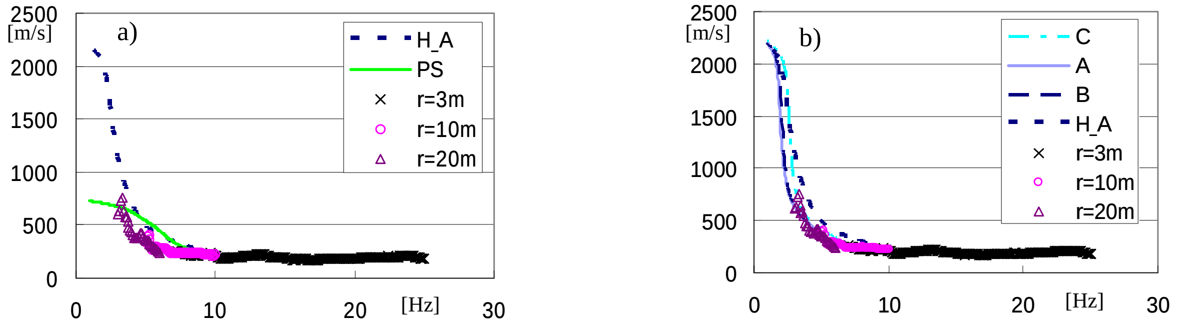

Fig.1 Dispersion curves by micro tremor and Ralyeigh wave velocity of various models

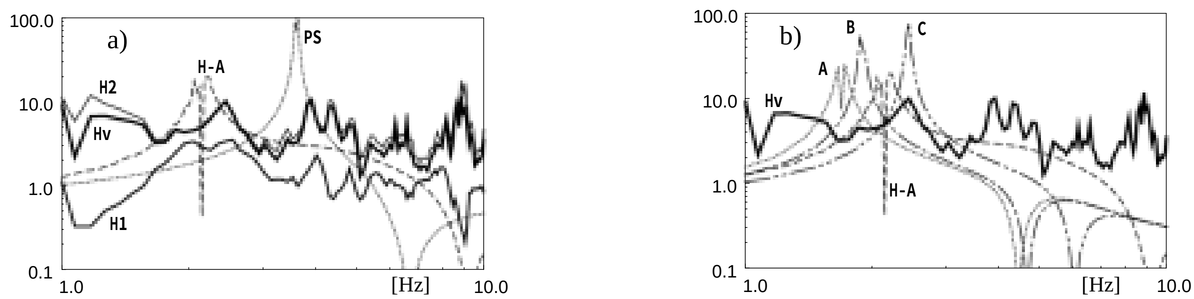

Fig.2 H/V spectra and H/V ratio of Rayleigh wave fundamental mode trajectory

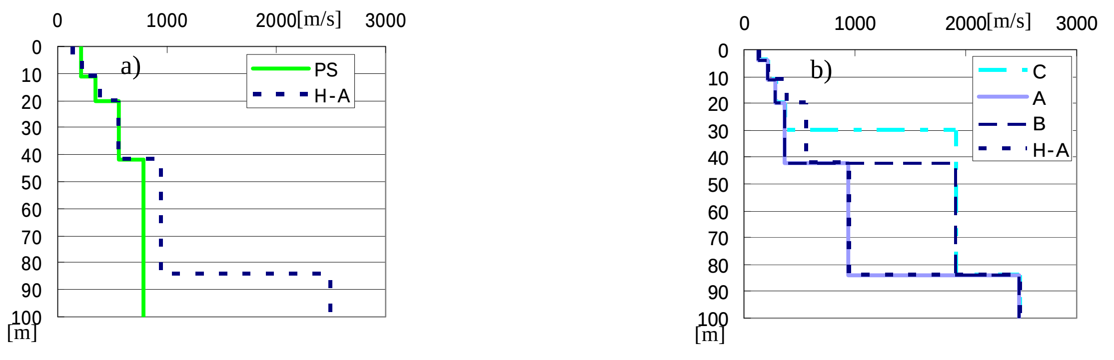

Fig.3 Shear wave velocity structure of subsurface models

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