# Comparison of subsurface models derived from different physical quantities in the inversion based on microtremors and earthquake motions

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1. Introduction
We can make a subsurface model using horizontal to vertical spectral ratio (HVSR) of earthquake motions at single point on the ground surface based on diffusion wave field theory (Kawase et al., 2011). In addition, we can keep the accuracy of the subsurface model by combining a receiver function (RF) even at a thick sedimentary site (Motoki et al., 2016). If the subsurface model can be estimated from records at single point on the ground surface with sufficient accuracy, it can be applied to thousands of stations deployed nationwide, which will lead to the advancement to make a comprehensive model. It is important to confirm the validity of the subsurface models in comparison with the results of other geophysical surveys, such as PS logging and microtremor array exploration. In this report, for the KiK-net Atsuma station IBUH03, we estimated the subsurface model by individual inversions and joint inversions with HVSR, RF, and microtremor exploration. We evaluated which model could be properly represented from the reproducibility of the earthquake motions.

2. Method and data
We calculated HVSR and RF using the records at the ground surface of IBUH03. The phase velocity by microtremor exploration was referred to Kogawa et al. (2019). We inversed the subsurface models using the hybrid heuristic method (Yamanaka, 2007). The model with the smallest error was adopted as the estimated model. At the time of inverse analysis, we individually used HVSR, RF, and phase velocity. We also jointly used RF, HVSR and the phase velocity. Vs and Vp were constrained so that Vs and Vp were not lower than those of the upper layer.

3. Inversion result
Compared with the PS logging model, the models derived from the phase velocity had a slightly slower Vs, and the other model had a slightly faster Vs. For the depth of seismic bedrock, the models were estimated in the range from 5,000 m to 7,500 m, similar to J-SHIS model. Regarding the difference between the single and the joint inversion, there was no significant difference in the deep subsurface model when HVSR was added to RF. When the phase velocity was added, the substrate depth became shallower.

4. Validation of subsurface models using earthquake motions
For the validation, goodness of fit (GOF) by Anderson (2004) was applied with three indicators; the first one is the transfer function between the vertical array; second one is the accuracy of the simulation at the ground surface; the last one is the propagation time from the downhole to the ground surface. In the simulation, we estimated the earthquake motions at the ground surface by the one-dimensional wave propagation theory with the input records at the borehole. Then GOF in response spectra is calculated. The propagation time was calculated based on the seismic interferometry, and the observed time was compared with the vertical S wave travel time of the model.
We found that the GOF resulted in two different group on the reproducibility of earthquake motions. First group was that the amplitude of the transfer function and the response spectrum of the ground record

 

were highly reproducible. Second group was that the phase of the transfer function and the propagation time were highly reproducible. For the first group, the single model with HVSR and the joint model with HVSR and RF were inverted. For the second group, the single model with phase velocity and the joint model with all quantities were included. There were no models that satisfy both groups simultaneously, primarily due to the effect of irregular boundary of sedimental layers, which is our task to be solved.

Keywords: Horizontal to vertical spectral ratioo, Receiver function, Phase velocity, Inversion of subsurface models