Estimation of seismic motion at depth from records at a ground surface station without assumption of plane wave incidence

*Tomotsugu Watanabe[1], Hiroshi Takenaka[1], Masanao Komatsu[1], Mitsutaka Oshima[2], Takeshi Nakamura[3]

1. Okayama University , 2. Shimizu Corporation, 3. National Research Institute for Earth Science and Disaster Resilience

To evaluate the seismic stability of shallow subsurface structure and the response of buildings to ground motions, we often need the distribution of seismic wavefield incident on a given subsurface level, which is estimated from the ground motion at a free surface position. It is currently conventional that the incident wavefield at depth is estimated by assuming a vertical incident plane wave for every component. However, this conventional approach assumes that the vertical and horizontal components of the seismic wave independently propagate as P-wave and S-wave, respectively, and the derived seismic motion is then identical at any horizontal positions on the subsurface level. We have proposed a new method to evaluate the subsurface incident wavefield from a surface record without assumption of plane-wave incidence at the previous presentation (Takenaka et al., 2019, SSJ Fall meeting). This method needs a horizontally-layered model including not only the target evaluation depth but also earthquake source. We calculate the synthetic seismogram at the surface station and the incident wave at the subsurface evaluation point. We then deconvolve the subsurface incident wave with the surface synthetic motion to get the transfer function and convolve it with the surface record. Replacing the incident wave at depth by the synthetic seismograms at the subsurface point, we can estimate the seismic motion at this point (Fig. 1).

In this study, we apply the new method to real event records which were observed both at surface and subsurface levels and compare the estimated seismogram by our method with the subsurface record and one obtained by the conventional method to confirm effectiveness of our method. We employ the local strong-motion records at a KiK-net, NIED station in western and central Tottori. We could successfully recover the subsurface records by our method. Fig. 2 shows the comparison of the velocity waveforms at depth of 100 m estimated by the proposed and the conventional methods for the evaluation point with a horizontal offset of 1 km from the surface station. Red and green lines indicate the seismograms estimated by the proposed and the conventional methods, respectively. They have a clear difference in the phase. If the evaluation point is located at a deeper position, each waveform differs both in the phase and the amplitude. This is because the conventional method is not able to consider the effect of the oblique incidence. The proposed method is also very robust to errors in the assumed focal mechanism and the structure model deeper than the evaluation point, and sensitive to the used shallower structure model. We will further discuss about the spectra in the frequency domain and the relationship between the estimated waveform and the shallow structure.

Keywords: seismic motion, plane wave, strong motion, subsurface wavefield

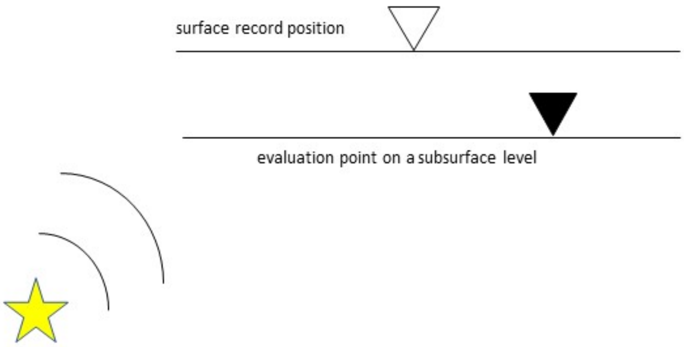

Fig. 1. Schematic view for the proposed method. White and black triangles indicate the surface record position and the evaluation point on a subsurface level, respectively. Star denotes the hypocenter.

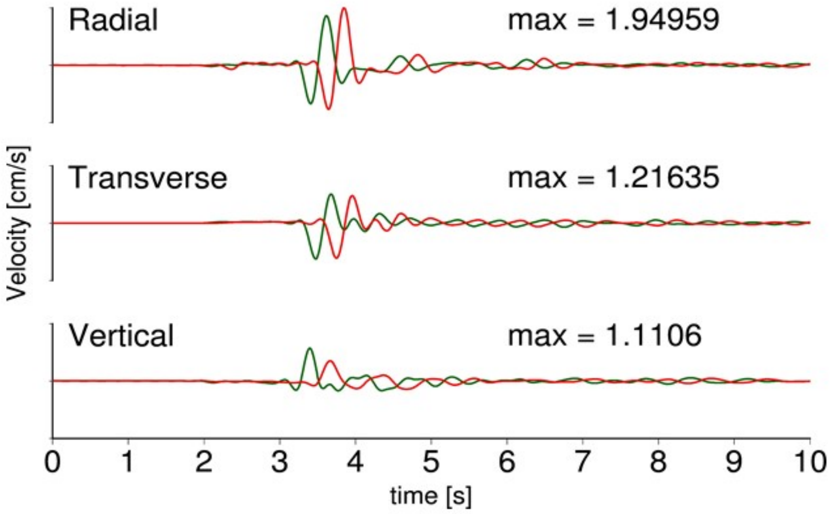

Fig. 2. Comparison of velocity estimated at depth of 100 m by the proposed and the conventional methods at KiK-net station, SMNH01. Red and green lines indicate waveform from the proposed and the conventional methods, respectively. The evaluation point has a horizontal offset at 1 km from the surface station.