Continuous observation in travel time difference of ACROSS signal using seismic array

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Experiments using ACROSS vibrators and seismic array were carried out for one month in a vault at Mizunami, Gifu Prefecture, Japan. ACROSS (Accurately Controlled Routinely Operated Signal System) is a system to monitor the temporal variation in seismic velocity with high resolution using a precisely controlled sinusoidal signal, which repeats accurately. We deployed a seismic array with 15 seismometers in the cross-shaped vault at the distance of 2.4 km from the ACROSS source. We continuously operated two ACROSS sources with frequency modulation centered at 17.52 and 25.53 Hz, modulation amplitude of 2.5 Hz and modulation period of 20 seconds. In this study, we investigated a cause of temporal variations in travel time to improve an accuracy of travel time for some dominant phases in a static structure.

Transfer function between the ACROSS source and each seismometer was obtained by applying a deconvolution to the observed data by a theoretical force of the source. We evaluated a propagation direction and an apparent velocity of some dominant phases using the semblance method. The P and S waves were arrived at 0.65 and 1.25 seconds with apparent velocities of 4.0 km/s and 2.2 km/s, which was interpreted as refracted waves from the basement layer of granite. Temporal variation in travel time of the refracted P wave and the refracted S wave was calculated using cross-spectrum density refer to the first calender time. Time delay was derived from phase delays for each frequency (Ikuta et. al., 2002). We obtained not only the time delay but also the variation in apparent velocity using the array data.

Travel time difference had fluctuated 1 ms in the P and S waves for 1 month, and the uncertainties were within 0.1 ms and 0.05 ms, respectively. It showed a variation with a period of 1 day with the value of about 0.5 ms at a maximum in the S wave. Phase variation on the source foundation also showed the similar fluctuation pattern, but the value was about 0.1 ms at a maximum, which corresponds to 20 % of the variation observed at the array. Temporal variation in temperature shows the similar pattern with those variations. Ikuta et. al. (2002) suggested that the phase variation around the source is affected by the variation of the rigidity of a surrounding rock, and they reported that the variation in travel time difference depends on a phase variation on the source. We explain a cause of the difference, and show a consistent model to interpret the temporal variation in travel time for these two experiments.

We consider an effect of the perturbation of physical properties on wavefield derived from scattering theory. Our investigation shows that the refracted wave has some sensitivity to the velocity variation near the surface. It satisfies the observed travel time variation. We will report the sensitivity and the effect to the travel time by a variation of temperature around the surface.