Estimation of surface wave dispersion curves for high resolution surface wave tomography using dense ambient noise data acquired by distributed acoustic sensing

*Tatsunori Ikeda[1], Takeshi Tsuji[1], Masanao Shinohara[2]

1. Kyushu University, 2. University of Tokyo

Recent development of distributed acoustic sensing (DAS) technology makes it possible to observe dense seismic data. In offshore environments, continuous seismic data were acquired by DAS using existing fiber optic cables and were utilized to estimate S-wave velocity profiles by extracting Scholte waves from surface-wave analysis (e.g., Spica et al., 2020; Cheng et al., 2021).

In previous surface-wave analyses using ambient noise recorded by DAS, surface wave dispersion curves have been estimated by multichannel records through array analysis such as f-k analysis or multichannel analysis of surface waves (MASW; Park et al., 1999). 1D S-wave velocity structure can be then estimated by inversion of experimental dispersion curves. By assembling each 1D S-wave velocity structure estimated at different locations, 2D S-wave velocity structure along fiber optic cables can be estimated. Such multichannel-based approaches enable to estimate phase velocity dispersion curves stably because higher modes of surface waves can be separated in f-k domain. However, 1D S-wave velocity structures estimated by multichannel based-approach have limited horizontal resolution as they represent averaged S-wave velocity structures within channels used in estimation. Another surface-wave analysis to estimate S-wave velocity distribution is surface-wave tomography using phase velocity dispersion curves between station pairs. If we can estimate dispersion curves between many channel pairs from dense seismic data of DAS, they can be used to estimate high resolution S-wave velocity structure with surface-wave tomography.

Here we propose a new method to estimate reliable two-station phase velocity dispersion curves utilizing dense seismic data of DAS. The proposed method is based on the zero-crossing method of Ekström et al. (2009), in which phase velocities are estimated from zero-crossing frequencies of real parts of cross-spectra between station pairs. The drawback of this approach is that if different modes are dominant in different frequencies, estimating dispersion curves is difficult because we determine a unique dispersion curve considering continuity of phase velocities in the frequency direction. On the other hand, our approach uses zero-crossing points in space (channel distance) direction for a fixed frequency, owing to short channel intervals of DAS. In the proposed method, we can easily estimate a unique phase velocity considering consistency in space direction without paying attention to change in dominant modes. Once we determine the zero-crossing channel spacings, phase velocities for arbitrary channel spacings would be estimated by interpolation.

We applied the proposed approach for ambient noise data recorded by DAS using the existing fiber optic cable on the ocean bottom in the Sanriku Region, Japan. We computed cross-spectra between channel pairs, and constructed gathers of cross-spectra with the same mid points (i.e., CMPCC gathers). For each CMPCC gather, the dispersion curves were estimated at each frequency and channel spacing by the proposed method. Furthermore, by applying surface-wave tomography for estimated fundamental and first higher modes of dispersion curves, we estimated 2D S-wave velocity structure along the fiber optic cable. The resulting S-wave velocity structure shows the low velocity region observed in the previous

study of Spica et al. (2020), who applied array-based surface-wave analysis for ambient noise data using DAS in the same region.

Thus, using the proposed approach, phase velocity dispersion curves between channel pairs can be estimated from dense ambient noise data by DAS, even if different modes are dominant. By applying surface-wave tomography to dispersion curves between many channel pairs, high-resolution S-wave velocity structure can be estimated.

In this study, we used seismic data acquired for Sustainable CCS Project by Ministry of Environment, Japan.

Keywords: surface wave, DAS, seismic interferometry, tomography

