Changes in phase velocity of Rayleigh waves at the Hinode area, Itako, Ibaraki, Japan, due to the construction by the ground water lowering method: A case study of the miniature array analysis of microtremors

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The Hinode area, Itako, Ibaraki, Japan suffered devastating disasters of liquefaction by the 2011 off the Pacific coast of Tohoku Earthquake. The Itako City has been conducting the construction method called the ground water lowering method to avoid the second devastating liquefaction by some huge earthquakes in the future. We report the changes in phase velocity of the Rayleigh waves at the Hinode area between two periods before and after the construction work starting, as a case study of the miniature array analysis of microtremors (Cho et al., 2013).
The construction period of the ground water lowering method was from April 2013 to March 2016. Currently, drain pipes has been buried at the depth of 3m along all paved roads in the Hinode area following that method. The ground water has been pumped up since May 2016. It is evaluated that a large liquefaction will never be met again by lowering the water level to the depth of 3m and keeping it at all times (Itako City, 2016).
We conducted measurements of microtremors using miniature arrays at an interval about 200m along an east-west survey line with the length of 3.2km, which crossed the Hinode area (about 2.8x1.4km) and its surroundings. The microtremor array used there was basically a set of a standard four-point array with a radius of 0.6m and a three-point irregular array with a radius about five meters. The observation duration was about 15min at each point. These microtremor surveys were conducted on August 2012 and on the begging of May 2013. Meanwhile, Yokota et al. (2016) conducted surface wave surveys on December 2012 along three survey lines with lengths from 1.2 to 1.6km, which includes the Hinode area and the northern extensions. In this study, we regard the data from the east-west survey line of microtremors and the two north-south survey lines of surface waves as the "data before the construction work starting".
As the "data after the construction work starting", we conducted measurements of microtremors using miniature arrays along the above three survey lines on September and October 2015. In the field measurements, we took care that each installation point of the microtremor arrays was the same as before. We deployed microtremor arrays at the interval about 100m along the surface wave survey lines. Importantly, all measurements of microtremors were conducted by installing the seismometers on the shoulder of a paved road, so that it is expected that the data after the construction work starting include the direct effects of the construction.
We analyzed the microtremor data along the east-west survey line and compared between the dispersion curves from the data before and after the construction work starting. As the result, it was shown that phase velocities obtained within the Hinode area increased especially in high frequency ranges. On the basis of a simple conversion method from a dispersion curve to an S-wave structure, these changes appeared to correspond to the increase in the S-wave velocities to the depths shallower than several meters. Similar features can be seen in the S-wave structures obtained by the microtremor method along the two survey lines of surface waves. This means that the general pattern of the distribution of the S-wave velocity obtained by the microtremor method is very similar to that obtained by the surface wave method with the exception of one point: the S-wave velocities to the depths shallower than several meters in the Hinode area by the microtremor method was particularly high (Fig. 1).

In this way, we observed changes in S-wave velocity only in the shallow portions in the Hinode area. This is qualitatively natural and may show the potential of the miniature array analysis of microtremors. We will make detailed examinations on the limitation and possibility of the miniature arrays in more qualitative manner.

Cho et al., 2013, Geophysics, 78, KS13-KS23.
Itako City, 2016, http://www.city.itako.lg.jp.
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Keywords: microtremor, array, surface wave, liquefaction, the 2011 off the Pacific coast of Tohoku Earthquake, the ground water lowering method