Detection of Drop and Recoverly Processes of Ground Shear Modulus by Using Coda Waves at the 2000 Western Tottori Earthquake

Kaoru Sawazaki[1]; Haruo Sato[1]; Hisashi Nakahara[1]; Takeshi Nishimura[1]

[1] Geophysics, Science, Tohoku University

sawa@zisin.geophys.tohoku.ac.jp

Professor Aki proposed a powerful method to measure the relative ground amplification by using spectral ratio of coda waves. By applying this method to a vertical array, we can estimate the site amplification from the spectral ratio of surface to borehole seismographs.

Strong ground motions sometimes decrease ground shear modulus and increase attenuation coefficient. As a result, both peak frequency and amplification of site response of S-waves decrease. Temporal changes of peak frequency of site response enable us to detect the recovery process of shear modulus of the ground subject to strong motions. In this study, we detected the drop and recovery processes of ground shear modulus by measuring the spectral ratio at the TTRH02 site (Hino-town, Tottori- Pref.) of the KiK-net associated with the Western Tottori Earthquake (MJMA7.1, 35.3N, 133.4E).

Two strong-motion seismometers are installed on this site. One is placed on the surface and another is installed at 100 m depth. According to the well log data, gravel layer with the shear wave velocity (Vs) of 210 m/sec is accumulated from the surface to 11 m depth, and granite and andesite layers with Vs of 340 to 790 m/sec continue from 11 to 100 m depth. The horizontal maximum acceleration of the mainshock was 1109 gal on the surface and 607 gal at 103 m depth.

First, we calculate the surface/borehole spectral ratio of direct S and S-coda for the time windows of 10 sec-long that are shifted from the S-wave onset until 280 sec later. The results show that the spectral ratio obtained for a time window of 0 to 10 sec after the S-wave onset has its peak frequency at 1 to 2 Hz with the maximum amplitude of about 20. The ratio for 10 to 50 sec window shifts its peak frequency to 2 to 4 Hz with the maximum amplitude of 30 to 90. A new peak appears at 4-5 Hz after 50 s from the S-wave onset, which is stable until 280 s after S-wave onset.

Subsequently, we calculate spectral ratios for a foreshock, which occurred three months before the mainshock, and those for 59 aftershocks, which occurred 3 days to 4 years after the mainshock. Epicentral distances of these events are less than 20 km and their magnitudes are ranging from 3.0 to 4.5. Their horizontal maximum accelerations were distributed from 10 to 180 gal. Setting a time window at 10 to 30 sec after the S-wave onset, we calculate the surface/borehole spectral ratio for each event. The peak frequency of aftershocks occurring within 10 days after the mainshock was at 5-6 Hz. The peak frequency gradually increased and reached to 7-8Hz, which is almost equal to the peak frequency for the foreshock, by 2 years after the mainshock. The spectral ratio at 7-9 Hz also increased and approached to the ratio at the foreshock.

We examine temporal changes of shear strain on the surface. The shear strain is calculated by dividing the velocity amplitude by the surface S-wave velocity. The observed shear strain for the mainshock is larger than 10ˆ(-4) with maximum of 6 times 10ˆ(-3) for 40 seconds after the S-wave onset. This strain level is generally considered to be a threshold above which reduction of shear modulus occurs. Contrary, the strain after 40 seconds from the S-wave onset is almost lower than 10ˆ(-4), and that coda of the foreshock and aftershocks are much smaller than 10ˆ(-4).

We speculate that the temporal change of the spectral ratio for 40 seconds after the S-wave onset at the mainshock may be related to the increase of shear modulus according to the decrease of strain level. Furthermore, the spectral ratio of coda of aftershocks also increased and approached to the ratio of the foreshock as time passes.

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