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Case study on the wavefield in the 3D structure including sedimentary basin and the effect of source depth on it

ARISUE, Maho[1] ; KAKEHI, Yasumaro[1*]

[1]Faculty of Science, Kobe University

It is widely recognized that the existence of sedimentary layers has a great influence on the excitation of surface waves. During the 2011 Fukushima-ken shallow inland earthquake (Mw 5.5, depth = 10.6 km), long-period surface wave was observed at a station in the Niigata sedimentary basin, which is over 150 km away from the epicenter, and its duration reached over 100 s. Long-period surface wave was observed also during the 2012 Fukushima-ken-oki deep interplate earthquake (Mw 5.7, depth = 53 km) at the same station, and its duration reached ˜100 s. Thus, significant difference was not seen between the surface wave duration in the Niigata basin of these two earthquakes despite of large difference of their source depths. This seems inconsistent with the recognition that surface wave is more efficiently excited by shallower source.

This study investigates the effect of source depth on the seismic wave filed in the sedimentary basin based on the numerical simulation using finite difference method for shallow and deep sources. The calculation area is from off the Fukushima Prefecture to the Niigata basin, and the following three simulations are performed.

In the simulation 1, a simple structure model composed of circular homogeneous sedimentary basin and background two-dimensional structure, two cases of source depths: 5 km and 85 km, and source duration of 3 s are assumed. The result shows the duration of the surface wave in the sedimentary basin is ˜50 s for the both shallow and deep sources, and large difference is not seen the two different source depth cases. At the station prior to the basin, wave duration for the shallow source is ˜10 s longer than that for the deep source. This difference of 10 s is shorter than the long duration of 50 s in the sedimentary basin, and this can explain the result that large difference is not seen in the basin.

In the simulation 2, a simple structure model composed of circular homogeneous sedimentary basin and background two-dimensional structure, as in the simulation 1, is assumed, and the case study on the material property values of the homogeneous basin is done. Two cases of source depths: 5 km and 75 km, and source duration of 3 s are assumed. The result shows longer duration of seismic waves is seen in the basin for smaller value of S-wave velocity of the basin medium (˜125 s for Vs = 0.5km/s, ˜90 s for Vs = 1.0 km/s, and ˜40 s for Vs = 2.0 km/s). This is interpreted to be because of larger arrival time difference of S-wave and surface wave for smaller S-wave velocity of the basin.

In the simulation 3, realistic complex three-dimensional structure model is assumed both for the sedimentary basin and for the background structure. We use the three-dimensional model by Koketsu et al. (2012), two cases of source depths: 5 km and 75 km, and source duration of 3 s. Long wave duration of ˜90 s is obtained both for the shallow and deep sources. The maximum amplitude at the station is the sedimentary basin is ˜2 times (for the deep source) and ˜6 times (for the shallow source) larger than that at the station prior to the basin.

Comparing the result of the realistic three-dimensional model case (simulation 2) and that of the simple structure model case (simulation 2), more complex and more continuous wave-packet with long duration is seen in the basin in the former case than that in the latter case. On the other hand, siginificant difference is not seen in the amplitude and duration at the station prior to the basin, both for the shallow and deep sources. This result suggests the wavefield in the sedimentary basin is mainly affected by the basin structure itself, rather than the structure model of the path from the source to the basin.

Keywords: sedimentary basin, surface wave, numerical simulation, source depth