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Excitation and propagation process of long-period pulse motion in the Kanto basin

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Large, shallow earthquakes can excite long-period (2-15 s) surface waves in distal sedimentary basins. Long-period ground motion has been recognized through these studies that the propagation of long-period waves in sedimentary basins is related to the depth of the basement rocks and its topology. However, the dense seismic network in the Kanto basin has revealed the anomalous propagation of a large-amplitude pulse wave with period of 6-7 s in at Shinjuku area, a center of Tokyo, during the 2004 mid-Niigata earthquake. Such large long-period shaking causes significant resonance of high-rise buildings. It is therefore necessary to clarify the existence of such long-period pulses in order to establish guidelines for disaster prevention.

In this study, the long-period pulse is investigated by analyzing a large number of records acquired at 329 stations in the Kanto basin, including the SUPREME (Tokyo-Gas) network, in addition to SK-net, and K-NET. The times, orientations, and polarities of records from the SK-net and SUPREME were corrected by interference analysis with data from K-NET sites so as to allow fine visualization. Visualization of the wave energy distribution revealed that the pulse is excited near the center of Saitama, and propagates toward Tokyo Bay, passing by Shinjuku. The corridor for this pulse is 10 km wide, and extends for 50 km. The phase velocity of the pulse is estimated to be 1.5-2.2 km/s and group velocity of 0.5 km/s by using MUSIC method. Particle motion analysis indicates that the long-period pulse consists of Love waves.

The numerical simulation conducted using the Earth Simulator was performed for the 2004 mid-Niigata earthquake based on a fault rupture model derived by inversion of strong motion (Hikima and Koketsu, 2005). At first, the 3D subsurface model employed was constructed for strong motion prediction (Tanaka et al., 2006). Although the simulated wave are in good agreement with observations at sites between the epicentral area and Saitama, the long-period pulse in the Shinjuku area is not reproduced by this structural model.

To reproduce the local long-period wave, the structural model was refined by considering the development of an Airy phase was defined about a stationary point of the dispersion curve for the group velocity of surface waves. After a number of simulations using a variety of structure models, the effect of the Airy phase enhancing structure was found to be most important in reproducing the long-period pulse. Through refinement of the simulation, a channel-shaped structure was found to reproduce the properties of the long-period pulse well. Further simulations were performed using the subsurface model including the channel structure, and the amplitude and duration of the long-period pulse were reproduced well.

This long-period pulse was excited only during the 2007 off-Niigata and the 2004 mid-Niigata earthquake. The present results suggest that the development of the Airy phase is necessary for the emergence of the large long-period pulse in the channel structure, which does not occur when the horizontal incident angle is greater than 20 degree.

The channel structure suggested by the present analysis is interpreted to correspond to Holocene sediments and the Narita layer, which is distributed as a small-scale soft shallow layer along the Arakawa River in central Saitama. Little attention has been paid in the past to the propagation of long-period motion in such small-scale heterogeneities

According to the National seismic hazard maps of Japan, the probability of earthquake occurrence on the Tohkamachi fault zone (M7.4) and Itoigawa-Shizuoka tectonic line fault zone (M7.4) are 2% and 20% over the next 50 years. These earthquakes fulfill the requirements for generating the long-period pulse. The destructive effect of such an earthquake considering this long-period pulse therefore requires careful scrutiny.