A study on the characteristics of amplitude and dominant period of long-period ground motions via 3D finite-difference simulation: A case study for the Kanto sedimentary basin

*Kazuo Yoshimoto[1], Kengo Kajikawa[1], Ayaka Izumi[1], Kaori Shimazu[1], Shunsuke Takemura[2]

1. Graduate School of Nanobioscience, Yokohama City University, 2. National Research Institute for Earth Science and Disaster Resilience

Introduction

In the Kanto sedimentary basin, long-period ground motions (LPGMs) are frequently observed for shallow local and regional earthquakes. It is reported that, in the Kanto sedimentary basin, the predominant period of LPGMs is mainly controlled by the bedrock depth of sedimentary basin (e.g., Yoshimoto and Takemura, 2014b), but with the exception of the area around the Tokyo Bay where the elongation effect due to low-velocity sedimentary layers is observed (e.g., Kajikawa et al., 2016). It is also found that the excitation of LPGMs is very complex and varies by epicentral direction of earthquakes (e.g., Yuzawa and Nagumo, 2012). For the better seismological understanding of these observations, we conducted 3D finite-difference (FDM) simulations using simplified velocity structure models of sediment-basement system to evaluate the effect of sedimentary structure and basement shape on the characteristics of strength and predominant period of LPGMs.

Simulation method and structure models

We conducted 3D FDM simulations for investigating the characteristics of LPGMs during shallow moderate earthquakes. For the evaluation of LPGMs for periods longer than 4 s, models with a volume of $150\times60\times72$ km^3 discretized by a grid interval of 0.15 km were used for this simulation. Other technical details are same as in Takemura et al. (2015). We used three sedimentary structure models referred from VSP measurements (Yoshimoto and Takemura, 2014a): Yokohama model (Y-model), Chiba model (C-model), and Iwatsuki model (I-model). We adopted four basement topography shapes: flat model (basement depth of 3.5 km) and flat + triangle-shaped hill (height of 2.5, 3.0, and 3.5 km) models. Structure beneath the basement was a stratified layered structure referred from the JIVSM (Koketsu et al., 2012). Pure strike- and reverse-type point source models, which excites Love and Rayleigh waves, respectively, were used in our simulations.

Result of numerical experiments

(1) Characteristics of Love and Rayleigh waves

Single-peak envelope of the fundamental-mode Love wave was found in the simulation using a strike-type source. In contrast to this, for a reverse-type source, multi-peak envelope of LPGMs appeared. These findings indicate that in the case of reverse-type source, LPGMs are constructed by superposition of not only fundamental- but also higher-mode Rayleigh waves. Dominance of horizontal amplitude over vertical amplitude observed for the simulations using a reverse-type source is consistent with this interpretation.

(2) Bedrock topography dependent PGV

Peak ground velocity (PGV) of LPGMs increases with increasing height of a triangle-shaped hill on the basement. This result is interpreted by the strengthening of the Airy phase of Love waves by the constructive interference of short period surface waves that are effectively excited and propagate at shallow depths. This phenomenon may correspond to the strong excitation of Love waves at the northern and western boundary of the Kanto basin.

(3) Local amplification of LPGMs
Local variation of the PGV of LPGMs was detected during surface wave propagation thorough adjacent sediments with different velocity structures. For example, propagation of Love waves from Y-model to C-model showed an amplification of LPGMs at period longer than about 5 s, and especially at about 10 s. This result successfully explains the observed local amplification of Love waves in the western coast of the central Boso Peninsula (Kajikawa et al., 2016).

The characteristics mentioned above were also found in large-scale FDM simulations using JIVSM or SBVSM (Masuda et al., 2016 SSJ). However, these simulations could not sufficiently reproduce the observed LPGMs around the Tokyo Bay and western edge of the Kanto Basin. To overcome this problem, detailed analysis of observed LPGMs, forward modeling and estimation of sedimentary structure via waveform inversion should be required.

Keywords: Long-period ground motion, Kanto sedimentary basin, Sedimentary structure, Surface wave, Maximum amplitude, Predominant period