The 2018 World Congress on
Advances in Civil, Environmental, & Materials Research (ACEM18)
Songdo Convensia, Incheon, Korea, August 27 - 31, 2018

Seismic Hazard Prediction of the 2017 Pohang Earthquake

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ABSTRACT

Korea is located in low-to moderate seismic region. The number of strong motion records in Korea are very limited. Ground motions recorded during the Pohang earthquake (M=5.4) provided valuable geophysical and seismological information, which are important inputs for seismic design. In this study, ground motions recorded during the 2018 Pohang earthquake are generated using the point source model considering Korean geological parameters and site amplification effect based on ground motion data obtained at recording stations. Using this model, ground motions are simulated for Korean peninsula. A contour map for response spectral acceleration is constructed withr ground motions generated by the Pohang earthquake using the proposed model.

Keywords: *Earthquake, ground motion, recording station, soil condition, point source model*

1. Introduction

The Korean peninsula located inside the plate is classified as a low to moderate seismic region, so that strong motion records are very limited. So, the 2017 Pohang earthquake that caused the largest human casualty and economic damage is valuable geophysical and seismological information, since digital instrumental observation began in 1978(Fig. 1).

(a) Damaged columns in Piloti type buildings	(b) Damaged masonry walls	(c) Damaged ceilings

Figure 1 Damaged structures from the 2017 Pohang earthquake

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Especially, in Pohang, there are many areas where soft layers and easy-to-liquefied layers are mixed. Therefore, the acceleration of ground motions is amplified by site-effects, resulting in many damages such as piloti buildings, old schools, and government buildings.
According to current seismic design criteria (ASCE7-16), when high-rise and freeform structures are targeted, seismic design should be done through time history analysis. The input ground motion to do this should use the selected instrument earthquake records or artificial earthquake records corresponding to the ground conditions of the area and adapted to the design spectrum.
The Korean Peninsula has a short history of recording ground motion. Also, it is located in the intra plate, so the number of significant strong motion records is little. Therefore, we have scaled and selected the overseas ground motion records according to the domestic code as the input data for dynamic analysis. However, if the input ground motions are different from the ground motions in the Korean peninsula for in seismic shape, frequency components and duration of strong motions, the biased results can be derived.
In this study, point source model was constructed to simulate ground motions during the 2017 Pohang earthquake. For considering the geotechnical conditions in Korea peninsula, the input parameters of the model proposed by Park et al. (2001) and Shin (2017) are used to SMSIM program that can generate ground motions developed by Boore (2005).
And, in order to consider the site amplification effect in each region, ground amplification factor was calculated based on the geotechnical acceleration data measured at each recording station in korean peninsula and then reflected in the simulated ground motions. To evaluate the accuracy of the proposed method, we compared the actual ground motions measured by the Pohang earthquake ($M_w = 5.4$) on November 15, 2017 and the ground motions generated by the proposed model for several recording stations. In addition, the ground motion during the 2017 Pohang earthquake was simulated throughout the Korean Peninsula, and a contour map of the peak ground acceleration was constructed using the proposed model.

2. Ground motion simulation model

Korea has limited information for fault structures in the Korean Peninsula. Therefore, it is assumed that point source available in Korea are earthquake sources. The model for simulating ground motions has been proposed based on the Fourier amplitude spectrum and has been improved by Boore and Atkinson (1987). By using this model, it is possible to generate artificial ground motion in the target region considering the magnitude of earthquake, earthquake distance, and seismic attenuation characteristics in the Korean Peninsula. Eq. (1) is a functional form of the Fourier amplitude spectrum of the proposed model.

$$A(f) = C \times S(f) \times D(f) \times I(f) \times Z\left(f\right) \tag{1}$$

where C is the scaling factor that defines the spectral amplitude, and $S(f)$ is the source spectral function that defines spectral shape of ground motion at the seismic source(reference distance: 1km), $D(f)$ is the decay function of spectral amplitudes as waves propagate to a site, $I(f)$ is the type of ground motion being computed: acceleration, velocity, or displacement, and f is the frequency. The parameters of the point source model considering geological characteristics for the Korean peninsula as follows:

$$C = \frac{\langle R_{\theta\phi} \rangle \cdot F \cdot V}{4\pi\rho\beta^3} \cdot \frac{1}{\gamma} \tag{2}$$

$$S(f) = \frac{M_0}{1 + (f/f_c)^2} \tag{3}$$

$$D(f) = \exp(-\pi\kappa_q f \cdot \gamma) \cdot \exp(-\pi\kappa_s f), \quad \kappa_s = 0.00131, \quad \kappa_q = 0.0001374 \tag{4}$$

$$I(f) = (2\pi f)^p \tag{5}$$

where $\langle R_{\theta\phi} \rangle$ is the average radiation pattern ($= 0.63$), F is the free surface effect ($= 2$), V is the partition factor of the horizontal component ($= 0.7071$), ρ, β are the soil density ($= 2.7\mathrm{g/cm^3}$) and the shear wave velocity ($= 3.68\mathrm{km/s}$) at the seismic source and γ is hypo-central distance, M_0 is the seismic moment, f_c is the corner frequency ($= 4.9 \times 10^6 \beta(\Delta\sigma/M_0)^{1/3}$), $\Delta\sigma$ is the stress drop($= 60\mathrm{bar}$) estimated by Shin(2017), and p is 0, 1, and 2 for displacement, velocity and acceleration, respectively.

The observed ground motion records include the site effect by the target stations. Unlike the rock sites, it is necessary to consider these effects when the artificial ground motion is simulated in the soil site where these effect is large. The site amplification factor ($Z(f)$) gives ground motion records site effect at each target recording site to distort and amplify their amplitude and shape. For considering site effect, previous research (Zhao et al., 2006) proposed H/V ratio method. Zhao et al. (2006) proposed using the ratio of the response spectrum of the horizontal component and the horizontal component applied with the 5% damped H/V response spectral ratios. Eq. (9) is a functional form of the site amplification factor.

$$Z(f) = \frac{RSA_H(f)}{RSA_V(f)} \tag{9}$$

Where $RSA_H(f)$ and $RSA_V(f)$ are the response spectral acceleration values of the horizontal and vertical components for each frequency component, respectively.

3. Simulation of artificial ground motions

Earthquake ground motions recorded at 3 sites (PHA2 station, DKJ station, CSO station) during the 2017 Pohang earthquake are simulated using the point source model with SMSIM software. Fig. 2 shows the comparison of the median and standard deviation response spectra of the artificial ground motion acceleration generated along with the geometric mean response spectrum of the horizontal ground motion observed at each station. Atkinson (2008) estimate the standard deviations of the response spectra applied at 5% damping ratio from 0.22 to 0.38 for each period in log (base (10) unit) scale for ENA regions in the intraplate. In this study, the ground motion is simulated by applying a standard deviation of 0.3 ($=\sigma_{\log}$) to the standard logarithm for all periods.

The response spectra of observed ground motions are estimated to be reproducible because they are evaluated within the maximum standard deviation ($=2\sigma_{\log}$) considered. This indicates that the point source model can be used for simulating ground motions for a particular earthquake event to conduct regional seismic risk analyses.

Fig. 3 shows the contour hazard map constructed using PGAs of ground motions simulated at all locations in Korean peninsula due to the Gyeongju earthquake. It is assumed that soil condition is assumed as S_B (normal rock, soil amplification factor = 1).

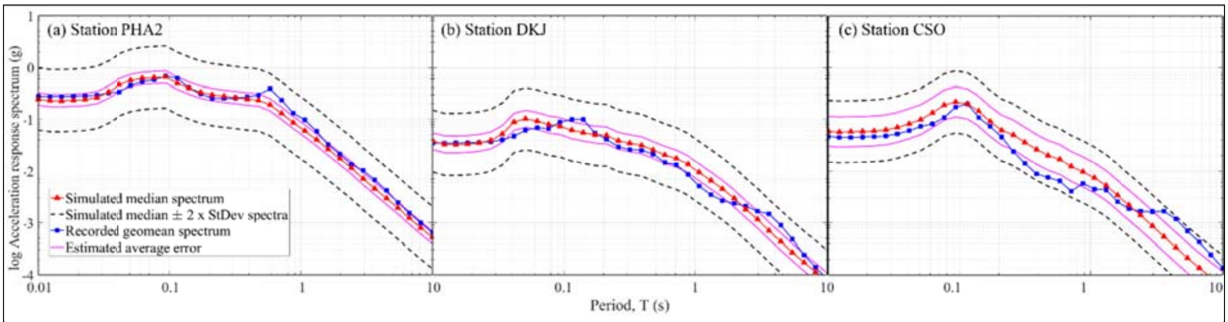

Fig. 2 Response spectra of simulated and recorded ground motions

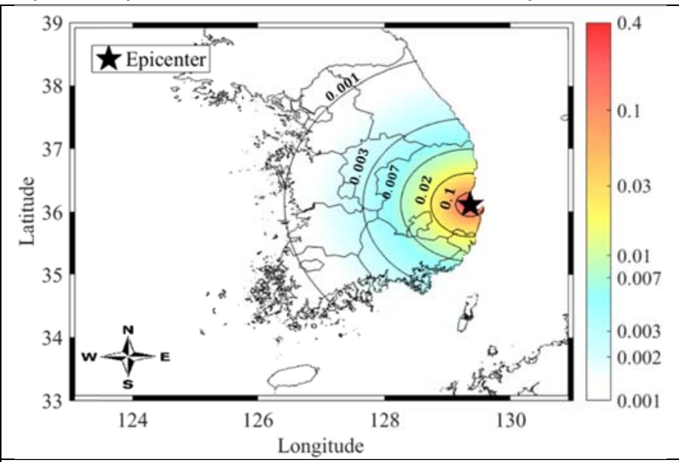

Fig. 3 Contour hazard map constructed using the peak ground acceleration of the simulated ground motions

4. Conclusions

In this study, ground motions recorded during the Pohang earthquake were simulated using the point source model. The following are the conclusions obtained from this study.

1. Ground motions occurred during the 2017 Pohang earthquake were properly simulated using the point source model.
2. The response spectra of generated ground motions matched the response spectrum of observed ground motions recorded during the 2017 Pohang earthquake. This indicates that the model used in this study accurately reflect site effect as well as the intensity of ground motions over all period ranges.

3. Seismic hazard contour map was constructed, which is associated with the Pohang earthquake. Such maps can be used when seismic risk analyses are to be conducted for existing and new structurers.

Acknowledgments

The research described in this paper was financially supported provided by National research foundation of Korea (NRF-2017R1A2B3008937).

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