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Enhancing the Accuracy of EXSIM-based Stochastic Ground Motion Modeling with Correction Factors for Path, Topographic, and Site Effects

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1. Introduction

Since seismic monitoring in South Korea began in 1978, the largest recorded events have been the 2016 M_L5.8 (M_w5.5) Gyeongju and 2017 M_L5.4 (M_w5.5) Pohang earthquakes. However, historical records and active fault investigations indicate the potential that earthquakes with magnitude exceeding 6 occurred in the past [1]. Strong ground motion prediction for such large earthquakes is essential to ensure the seismic safety of critical infrastructures such as nuclear power plants. To evaluate ground motion intensities for such large events, both empirical and stochastic modeling approaches have been employed [2]. Existing stochastic ground motion models often do not fully incorporate path, topographic, and site effects. In this study, EXSIM is used to simulate the Gyeongju and Pohang earthquakes. We perform residual analyses to assess path, topographic, and site effects. Correction factors derived from these analyses are incorporated into the model to improve the accuracy of predicted response spectra.

2. Methods and Results

2.1 EXSIM-Based Ground Motion Simulation

EXSIM is based on a finite-fault method in which the fault plane is divided into subfaults, each represented as a point source. Ground motions are calculated by summing the synthetic time histories generated from each subfault, considering source, path, and site effects. The source spectrum for each subfault is defined using parameters such as moment magnitude and stress drop. Path effects incorporate geometric spreading and anelastic attenuation. To account for site effects, frequency-dependent amplification factors are applied. Table 1 shows the parameters used in this study to simulate the Gyeongju and Pohang earthquakes. Figs. 1 and 2 compare the measured and predicted response spectra at seismic stations for the Gyeongju and Pohang earthquakes, respectively. For both earthquakes, the predicted response spectra at the majority of stations are in close agreement with the measured ones. However, MAS2 and WAN2 stations showed considerable residuals at high frequencies (≥ 3 Hz). These discrepancies, also reported by Park et al. [3], may be attributed to localized topographic and site effects that amplify high-frequency components of motion.

Table I: Simulation parameters for the Gyeongju and Pohang earthquakes.

Parameters	Values	
	Gyeongju	Pohang
Moment magnitude	5.5	5.5
Stress drop (bar)	127	40
Fault length/width (km)	5.5/3.7	6/5
Strike/Dip (˚)	24/70	214/51
Geometrical spreading	$R^{-0.9}$ ($R \leq 50$ km) $R^{-0.5}$ ($R > 50$ km)	
*Anelastic attenuation	GB: $197f^{0.659}$, GM:$365f^{0.498}$ OB: $211f^{0.626}$, YB: $330f^{0.400}$ YM: $279f^{0.813}$	
Site amplification	Site amplification factors for V_{S30} = 760 m/s [4]	

*In this study, different anelastic attenuation was assigned for each tectonic region (GB: Gyeongsang Basin, GM: Gyeonggi Massif, OB: Okcheon Belt, YB: Yeonil Basin, YM: Yeongnam Massif).

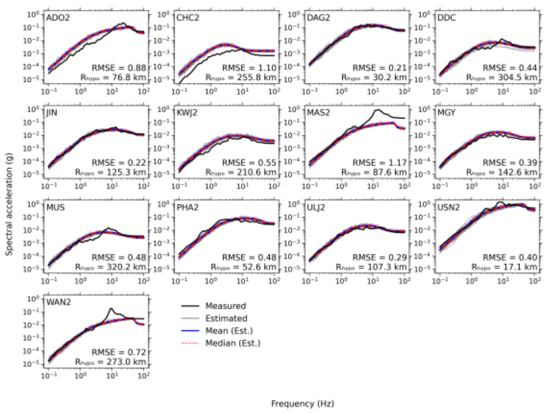

Fig. 1. Comparison of response spectra for measured and predicted ground motions for the 2016 M_w5.5 Gyeongju earthquake.

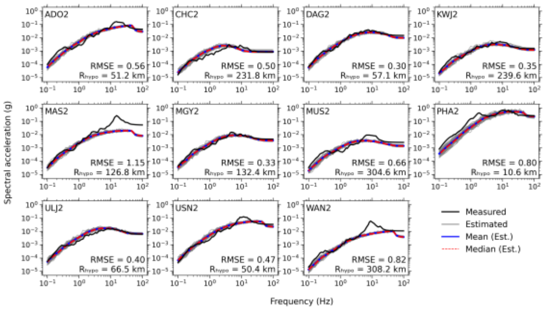

Fig. 2. Comparison of response spectra for measured and predicted ground motions for the 2017 M_w5.5 Pohang earthquake.

2.2 Development of correction factors

Residuals between measured and predicted response spectra were analyzed to develop correction factors for path, topographic, and site effects. The correction factors (CFs) for each frequency were determined as follows:

$$\text{Residual} = CF_{path} + CF_{Topo} + CF_{Site} \quad (1)$$

$$CF_{path} = c_0 + c_1 R_{hypo} + c_2\theta \quad (2)$$

$$CF_{Topo} = c_3 + c_4 RE_{300} + c_5 \text{Aspect} + c_6 \text{Slope} \quad (3)$$

$$CF_{Site} = c_7 + c_8 V_{S30} \quad (4)$$

where $c_{0\text{–}8}$ are regression coefficients, R_{hypo} is the hypocentral distance, θ is the azimuth from the station to the epicenter, RE_{300} is the relative elevation within a 300 m radius, Aspect is the direction that slope faces, Slope is the degree of inclination of a surface, V_{S30} is the average shear wave velocity up to 30 m depth.

Figs. 3 and 4 present the response spectra after applying the correction factors. The residuals were reduced at the majority of stations, with substantial improvements at high frequencies (≥ 3 Hz), particularly at MAS2 and WAN2. However, residuals at a few stations (MGY, MGY2, and JIN) slightly increased where Eq. (1) did not adequately represent the local trend; in such cases, station-specific adjustments may be required to decrease the residuals.

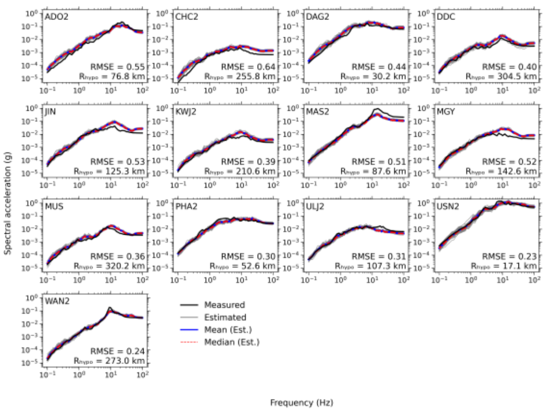

Fig. 3. Comparison of response spectra for measured ground motions and predicted ground motions with correction factors applied for the 2016 M_w5.5 Gyeongju earthquake.

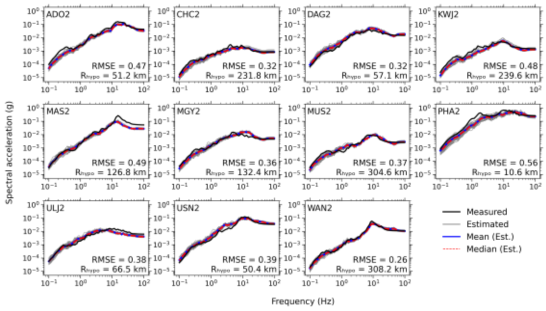

Fig. 4. Comparison of response spectra for measured ground motions and predicted ground motions with correction factors applied for the 2017 M_w5.5 Pohang earthquake.

3. Conclusions

We simulated the Gyeongju and Pohang earthquakes with EXSIM and analyzed residuals to develop frequency-dependent correction factors for path, topographic, and site effects. Applying the correction factors reduced residuals at most stations and enhanced the accuracy of the predicted response spectra at high frequencies (≥ 3 Hz), especially at MAS2 and WAN2. This correction factor approach improved EXSIM-based ground-motion modeling using six variables (R_{hypo}, θ, RE_{300}, aspect, slope, V_{S30}). At a few stations (MGY, MGY2, and JIN), residuals increased slightly, indicating that Eq. (1) did not fully capture local trends; in such cases, further station-specific refinements may be needed to reduce the residuals. Future work will refine the correction factors and expand the applications to additional seismic stations.

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REFERENCES

[1] Y-S. Kim, M. Son, J-H. Choi, J-H. Choi, Y-B. Seong, and J. Lee, Processes and Challenges for the Production of Korean Active Faults Map, Journal of the Geological Society of Korea, Vol.56(2), pp113-134, 2020.

[2] H. W. Jee and S. W. Han, Regional ground motion prediction equation developed for the Korean Peninsula using recorded and simulated ground motions, Journal of Earthquake Engineering, Vol.26(10), pp5384-5406, 2021.

[3] H-J. Park, H. Lee, and B. Kim, Correction factors for GMMs considering site and topographic effects in South Korea, Bulletin of Earthquake Engineering, Vol.20, pp.143-165, 2022.

[4] G. M. Atkinson and D. M. Boore, Earthquake Ground-Motion Prediction Equations for Eastern North America, Bulletin of the Seismological Society of America, Vol. 96(6), pp2181-2205, 2006.