Intensity measures selection for seismic responses of NPP components considering high-frequency ground motions

Duy-Duan Nguyen [a], Hyosang Park [a], Bidhek Thusa [a], Shinwook Yang [a], Yongmin Kim [a], Tae-Hyung Lee [a*]
[a] *Department of Civil Engineering, Konkuk Univ., Seoul 05029, Korea*
[*] *Corresponding author: thlee@konkuk.ac.kr*

1. Introduction

The peak ground acceleration (PGA), velocity (PGV), displacement (PGD), or other spectral intensities such as acceleration (S_a), displacement (S_d), are commonly selected for the seismic performance analysis of infrastructures. However, a number of studies pointed out that the aforementioned parameters might not always the best selections for seismic responses and damage analysis of civil structures [1-9]. The interrelation between earthquake intensity measures (IM) and building structures responses were investigated numerously, whereas it is rarely conducted in nuclear power plant (NPP) components. In this study, we perform a series of time-history analyses considering high-frequency ground motions to identify the best intensity measures for seismic responses of NPP components. A typical NPP structure in Korea is utilized for numerical analyses, in which three components including containment building, auxiliary building, and internal structures are modeled. Seismic responses of these components are observed in terms of the maximum drift and floor spectral acceleration. A series of Pearson's correlation coefficients are calculated to realize the correlation between each of 23 seismic intensity measures and NPP structure responses.

2. Methods and Results

2.1 NPP components model

The NPP APR1400 which built in Korea was selected for a numerical example. The lumped mass stick model in OpenSees [10] is used for modelling the structure. Fig. 1 shows the finite element model of the NPP components in OpenSees. It should be noted that, the base of structure was assumed to be fixed at the ground surface.

2.2 Ground motion intensity measures

Twenty-three seismic intensity measures are calculated for every ground motion record using SeismoSignal tool [11]. We used a group of 20 high-frequency ground motions which recorded in earthquake events in US and Korea for correlation analyses. All the ground motions are imposed to the model only in the horizontal directions.

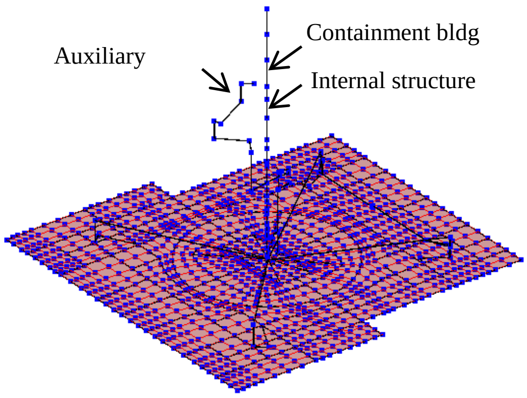

Fig. 1. Lumped mass stick model of APR1400 in OpenSees

2.3 Seismic responses of NPP components

For this study, the seismic responses of NPP components were obtained in terms of the maximum drift ratio and floor spectral acceleration at each component. Fig. 2 shows a representative example of time-history displacements and spectral accelerations of components.

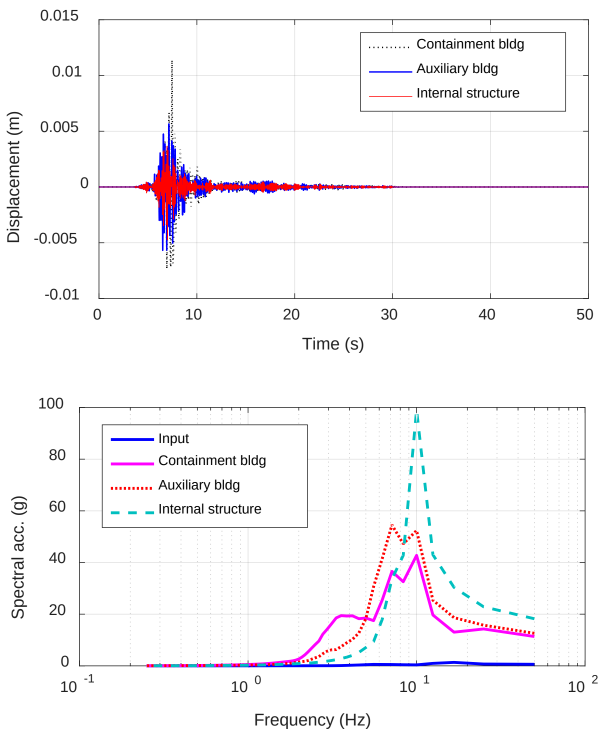

Fig. 2. Displacement (up) and spectral acceleration (down) of components under the 2016 Gyeongju earthquake (USN station, horizontal direction)

2.4 Calculated correlation coefficient

A series of Pearson's coefficients are calculated to measure the correlation between seismic responses of the NPP components and every 23 earthquake IMs. The equation of the correlation coefficient is referred in Ang and Tang [12]. Fig 3 shows the representative results of the calculated correlation coefficients. It can be found that specific energy density (*SED*) has the strongest correlation, followed by characteristic intensity (I_c), root-mean-square of velocity (V_{rms}), and Arias intensity (I_a). The poorest correlation IMs are the ratio of PGV/PGA, predominant period (T_p), mean period (T_m), and cumulative absolute velocity (*CAV*). Additionally, PGA, PGV, PGD, and S_a have medium correlation with components responses. This trend is observed for all three structure components.

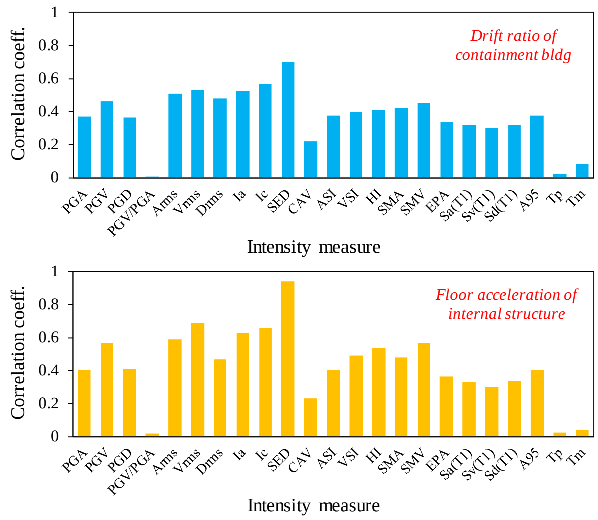

Fig. 3. Correlation between drift ratio (up) and floor spectral acceleration (down) and earthquake IMs.

3. Conclusions

The numerical model of NPP components with time-history analyses was performed using OpenSees taking into account high-frequency ground motions. A series of correlation coefficients were obtained to identify the best earthquake intensity measures for seismic responses of NPP components. The numerical simulation results demonstrate that the best indicators are specific energy density (SED), characteristic intensity (I_c), root-mean-square of velocity (V_{rms}), and Arias intensity (I_a). The poor correlated parameters are the ratio of PGV/PGA, predominant period (T_p), mean period (T_m), and cumulative absolute velocity (CAV).

REFERENCES

[1] Cao VV and Ronagh HR, Correlation between seismic parameters of far-fault motions and damage indices of low-rise reinforced concrete frames, Soil Dymanics and Earthquake Engineering, Vol.66, p. 202-112, 2014.

[2] Elenas A, Correlation between seismic acceleration parameters and overall structural damage indices of buildings, Soil Dymanics and Earthquake Engineering, Vol.20, p. 93-100, 2000.

[3] Elenas A and Meskouris K, Correlation study between seismic acceleration parameters and damage indices of structures, Engineering Structures, Vol.23, p. 698-704, 2001.

[4] Massumi A and Gholami F, The influence of seismic intensity parameters on structural damage of RC buildings using principal components analysis, Applied Mathematical Modeling, Vol.40, p. 2161-2176, 2016.

[5] Kostinakis K, Athanatopoulou A, and Morfidis K, Correlation between ground motion intensity measures and seismic damage of 3D RC buildings, Engineering Structures, Vol.82, p. 151-167, 2015.

[6] Chen Z and Wei J, Correlation between ground motion parameters and lining damage indices for mountain tunnels, Natural Hazards, Vol.65, p. 1683-1702, 2013.

[7] Padgett JE, Nielson BG, and DesRoches R, Selection of optimal intensity measures in probabilistic seismic demand models of highway bridge portfolios, Earthquake Engineering and Structural Dynamics, Vol.37, p. 711-725, 2008.

[8] Zhang YY and Ding Y, Selection of optimal intensity measures in seismic damage analysis damage of cable-stayed bridge subjected to far-fault ground motions, Journal of Earthquake and Tsunami, Vol.9, p. 1550003-1-18, 2015.

[9] Cao VV and Ronagh HR, Correlation between parameters of pulse-type motions and damage of low-rise RC frames, Earthquakes and Structures, Vol.7, p. 365-384, 2014.

[10] Mazzoni S, McKenna F, Scott MH, and Fenves GL. OpenSees command language manual. Pacific Earthquake Engineering Research Center, University of California, Berkeley USA, 2007.

[11] SeismoSignal - A computer program for signal processing of strong-motion data, available from *http://www.seismosoft.com*, 2016.

[12] Ang AHS and Tang WH, Probability Concepts in Engineering, Emphasis on Applications to Civil and Environmental Engineering, John Wiley & Sons, New York, 2007.