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Inelastic Seismic Response Assessment of Short Period Structures Subjected to High-Frequency Earthquakes

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1. Introduction

Much attention has been paid to describe inelastic seismic response of structures realistically. Especially in fragility analysis of NPP structures, inelastic energy absorption factor(F_μ) is utilized to represent inelastic behavior of the structure in a simple manner. Because inelastic energy absorption factor is a function of ductility demand(μ) and period(T) of the structure, it is expected that frequency component of an earthquake can affect the result. If inelastic energy absorption factor(F_μ) is affected by the frequency component of an earthquake, site-specific soil condition or frequency component of the earthquake of interest should be considered in the calculation of the factor. In this study, several real recorded earthquakes are divided into two groups depending on the frequency component of the earthquakes. For the two earthquake groups, inelastic energy absorption factor(F_μ) has been derived respectively.

2. Inelastic Seismic Response

In this paper, the influence of the frequency component of ground motion to inelastic energy absorption factor is described. All ground motion data were selected from real recorded time histories.

2.1 Inelastic Energy Absorption Factor

Inelastic single degree of freedom(SDOF) systems can be applied to the analysis of the inelastic behavior of structures. Inelastic energy absorption factor(F_μ), especially specified in fragility analysis of NPPs, is a factor representing inelastic behavior of the structure subjected to ground motions. Median seismic capacity can be evaluated by applying inelastic energy absorption factor(F_μ) to the elastic analysis result of a building. The relationship between inelastic energy absorption factor(F_μ), ductility demand, and period (F_μ-μ-T) has been proposed by several researchers [1-5]. Fig. 1. shows an example of the relationship done by some of the researchers. As shown in the figure, in general, proposed inelastic energy absorption factors increase as period and ductility demand increases. However, the ground motions considered in these studies generally had broad band frequency spectra. For the purpose of more realistic evaluation of the seismic response, therefore, some characteristics of ground motion should be considered in the assessment of inelastic energy absorption factor(F_μ).

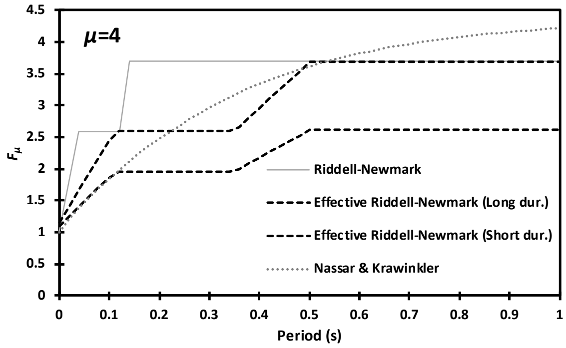

Fig. 1. Proposed F_μ - μ - T relationships (μ =4, Period: 0~1sec)

2.2 High-Frequency Earthquakes

High frequency earthquakes could amplify the response of short period buildings. Low-rise concrete shear wall buildings exist in NPPs, which are generally belong to short period structures[6], may show amplified response. In this paper, forty real recorded time histories are divided into two groups based on the PSD(power spectrum density) of each ground motion; 20 high-frequency earthquakes, and 20 low-frequency earthquakes. All selected earthquakes showed shear wave velocity over 760m/s which is corresponding hard rock or moderate rock site condition.

2.3 Analysis results

For the sake of simplicity, numerical analyses were conducted for ideal elastoplastic SDOF model. 5% damping were assumed for the system. F_μ-μ-T relationship were produced for each high-frequency and low-frequency earthquake. Mean value (F_μ) of 20 high-frequency earthquakes and 20 low-frequency earthquakes at each period showed a distinctive result. Fig. 2. shows the result. As expected, the mean value of total 40 earthquake motions (solid purple line) is well-matched to the relationship proposed by previous studies[1-5]. However, inelastic energy absorption factor(F_μ) of high-frequency earthquake (solid red line) always shows larger value especially for shorter periods less than 0.5sec. On the other hand, inelastic energy absorption factor(F_μ) of low-frequency earthquake (solid blue line) showed relatively small value. This result involves, for the same ductility demand, short-period structure including concrete structures in NPPs subjected to high-frequency earthquake yields higher inelastic energy absorption factor(F_μ) than low-frequency earthquakes. It means that the current proposed equation could underestimate the seismic capacity of the structure of short period when high frequency earthquake occurs. Because low rise concrete shear walls in NPPs are generally shows short fundamental period and the failure mode of the wall is defined as a drift ratio value in consideration of attached equipment rather than catastrophic collapse, inelastic energy absorption factor(F_μ) should take into account the frequency component of earthquake, or site-specific soil condition.

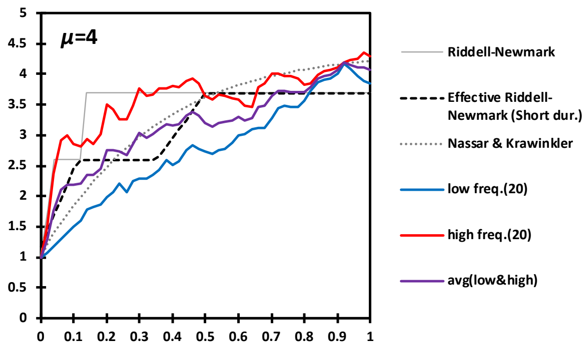

Fig. 2. Comparison of F_μ - μ - T relationships between high frequency earthquake and low frequency earthquake (μ =4, Period: 0~1sec)

3. Conclusions

Short-period structure subjected to high-frequency earthquakes showed generally larger inelastic energy absorption factor(F_μ) than that of lower-frequency earthquakes. This result yields the need for the consideration of site-specific soil condition or frequency component of the earthquake of interest in evaluating seismic capacity of NPP structures.

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