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Response of Base Isolation System Excited by Spectrum Compatible Ground Motions

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1. Introduction

Structures in a nuclear power system are designed to be elastic even under an earthquake excitation. However a structural component such as an isolator shows inelastic behavior inherently. For the seismic assessment of nonlinear structures, the response history analysis should be performed. Especially for the performance based design, where the failure probability of a system needs to be evaluated, the variation of response should be evaluated. In this study, the spectrum compatible ground motions, the artificial ground motion and the modified ground motion, were generated. Using these ground motions, the variations of seismic responses of a simplified isolation system were evaluated.

2. Time History Generation Methods

2.1Frequency Domain Method

The artificial ground motion generation method in the frequency domain is widely developed to synthesize the spectrum compatible accelerogram. In this method, the accelerogram is composed of sinusoidal waves, where, the phase angle spectrum is randomly generated and the amplifications of each frequency are obtained by several times of iterations to match the target spectrum. In this study, the software, P-CARES [1], was used for the generation of artificial time history set.

2.2 Time Domain Method

The frequency domain method is easy and powerful for an engineering purpose. However, it cannot reflect some characteristics of a real earthquake ground motion such as a non-stationary character, a coherence of each direction or a strong motion duration, etc. Therefore, in several design guidelines, recorded or modified recorded earthquake ground motions are recommended especially for the nonlinear seismic analysis.

In this method, a seed ground motion is selected and modified compatible to the target response spectrum in time domain maintaining the stationary character of the seed motion. The software, RspMatch [2] was used here. In this code, the tapered cosine wavelet is superposed on the seed ground motion time history. The time lags and the amplitudes of wavelets are determined to be compatible with target response spectrum with minimizing the change in the ground motion time history. Fig. 1 shows the target response spectrum proposed in the Reg. Guide 1.60 with 0.5 g peak ground acceleration, and the matched response spectrum by modification of the seed ground motion. Fig. 2 depicts the time history of the seed motion and the modified time history. As shown in this figure, the stationary character and the envelope of accelerogram have little difference in the seed and modified ground motions.

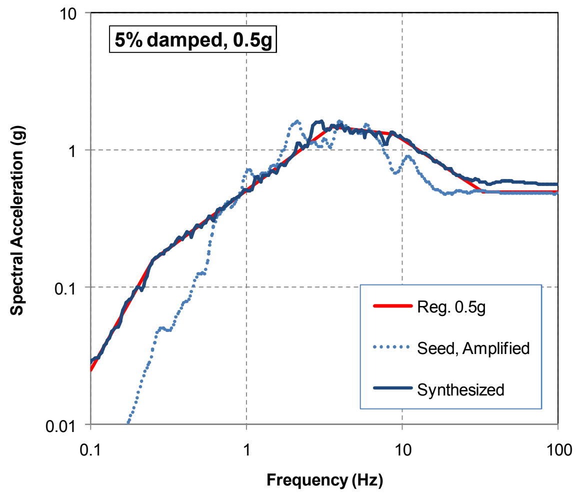

Fig. 1. 5% damped spectral acceleration of the modified time history using seed ground motion

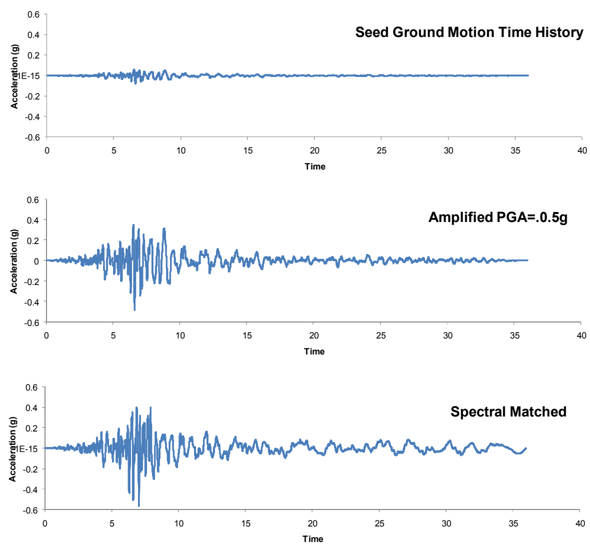

Fig. 2. Accelerograms of the seed motion, the amplified seed motion by the PGA, and the modified motion compatible to the target spectrum

3. Analysis and Result

3.1 Analysis Model

In the example model, the superstructure is assumed to be rigid body and the isolation system is modeled as the single degree of freedom with bilinear kinematic hardening behavior. The isolator has an effective stiffness of 8.91 ton/cm and the mass of superstructure is determined that the natural frequency of the single degree of freedom system is 0.5 Hz. The hysteresis curve and mechanical properties of this system is shown in Fig. 3.

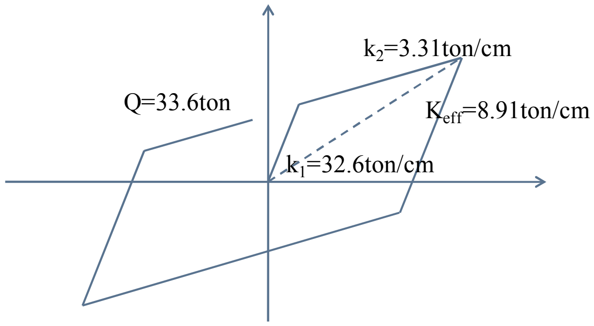

Fig. 3. Hysteresis curve of the single degree of freedom isolation system

3.2 Response of Isolator

For the evaluation of seismic responses, 7 sets of ground motions by two methods were generated. For the modified ground motion set, the seed ground motions were selected in various magnitude and distance bins. The example result of response history using the modified ground motion is plotted in Fig. 4.

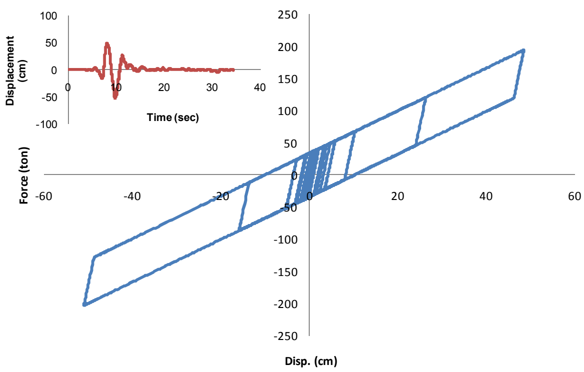

Fig. 4. Force displacement curve and displacement response history of the isolation system

First, the variations of elastic response spectra were compared because the iteration criteria are different each other. Moving averages of the spectral acceleration were calculated at 0.33 Hz which is the natural frequency with the effective stiffness corresponding to the maximum displacement. Its standard deviations were estimated to be almost the same value, which are 0.050 for the artificial set and 0.051 for the modified set. The maximum responses of displacements and forces by the two input motion sets are summarized in Table I. The standard deviation of the response by the modified set was about 2 times of that by the artificial set in spite of the same standard deviation in elastic response spectra. It represent that the variation of the nonlinear response is larger when input ground motions have realistic characters.

Table I: Response of the isolation system

	Artificial Ground Motion Input		Modified Ground Motion Input	
No.	Max. D (cm)	Max. F (tonf)	Max. D (cm)	Max. F (tonf)
1	61.9	238.2	50.1	199.3
2	61.9	238.2	34.0	146.0
3	50.4	200.4	56.3	219.7
4	50.5	200.5	50.3	200.0
5	54.6	214.1	43.7	178.1
6	53.7	211.0	45.5	184.0
7	47.8	191.6	34.2	146.8
Median.	44.2	180.1	54.2	212.8
Std. Dev.	0.101	0.085	0.194	0.157

4. Conclusions

In this study, the responses of a simplified isolation system excited by spectrum compatible ground motions were evaluated. The ground motions were synthesized by two methods. The variation of responses using the modified ground motion set was larger than that of artificial ground motion set. Therefore, a nonlinear analysis requires recorded or modified input ground motions to estimate the distribution of responses.

ACKNOWLEDGEMENT

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