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Effects on the Floor Response Spectra by the Nonlinear Behavior of a Seismic Base Isolation System

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1. Introduction

A nuclear power plant accident can leads to huge casualties, economic damage, and permanent contamination, such as the Russian Chernobyl nuclear power plant accident in 1986 and the Fukushima power plant accident after the great east Japan earthquake in 2011. An evaluation of safety being carried out for various risk factors of prevents for nuclear power plant accident. In general, an evaluation of the structural integrity was performed about seismic risk. In recent years, an assessment of integrity of internal equipment being carried out for earthquake loads owing to the possibility of severe accidents caused by the destruction of internal equipment or a blackout.

Floor response spectra of the structure should be sought for evaluating of the integrity of internal equipment. The floor response spectra depends on the characteristics of seismic base isolation system such as the natural frequency, damping ratio, and height of the floor of the structure. An evaluation of the structural integrity using the equivalent stiffness of the seismic base isolation system was satisfactory. However, the influence of a nonlinear of the isolated system is expected to have a huge difference in case of the floor response spectra, and research on this area is necessary.

Therefore, in this study, the effect of the non-linearity of isolated system in the floor response spectrum of the structure is analyzed.

2. The analysis model

2.1 Validation of the analytical model

A validation of the analysis model was performed, before an analysis of floor response spectrum on the seismic base isolation system is performed. The seismic base isolation system for the shaking table test [1] was used in this study, and the analysis model is as shown in Fig.1. The major specifications of the steel structure are listed in Table I.

Fig. 1. The seismic base isolation system for shaking table test

Table I: The major specifications of the steel structure

Member	Standard cross-sectional dimension H×B×t1×t2(mm)	Cross-section area A(cm2)	Unit Weight W(N/cm)
Column	350×175×7×11	63.14	4.96
Beam	300×150×6.5×9	46.78	3.67

The commercial software SAP2000 was used for the eigenvalue analysis. The analysis model is as shown in Fig.2.

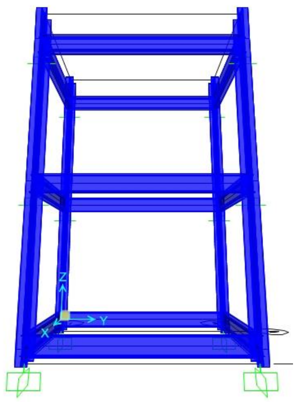

Fig. 2. The analysis model structures for shaking table test

Result of eigenvalue analysis was consistent with the experimental results as 0.577sec.

2.2 Establishment of isolated system analysis model

Additional mass was placed on the structure as shown in Figure 3 considering the total mass and eigenvalue of the containment building. The total weight of the analytical model was 30tonf.

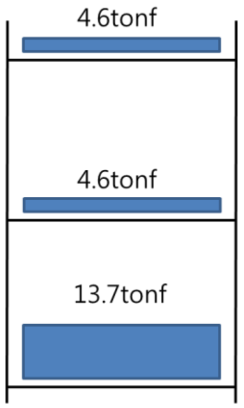

Fig. 3. The additional mass for analysis model

A rubber bearing isolated system was used for this study. In addition, the major specifications of the rubber bearing isolator are listed in Table 2.

Table Ⅱ: The major specifications of the rubber bearing isolator (Unit: N/mm)

Stiffness of lead (Kp)	4.81
Shear stiffness of rubber (Kr)	128
1st Stiffness (Ku)	11312
2nd Stiffness (Kd)	133
Load of cross-axis (Qd)	4089
Equivalent stiffness (Keq)	201

The rubber bearing isolators (total: 4ea) were installed below each column.

2.3 Input seismic acceleration

The ground acceleration generated to corresponding to the designed displacement of the rubber bearing isolator. The ground acceleration was used for an analysis of the floor response spectrum. The calculated ground acceleration is as shown in Figure 4. The ground acceleration was applied to the weak axis direction of the structures.

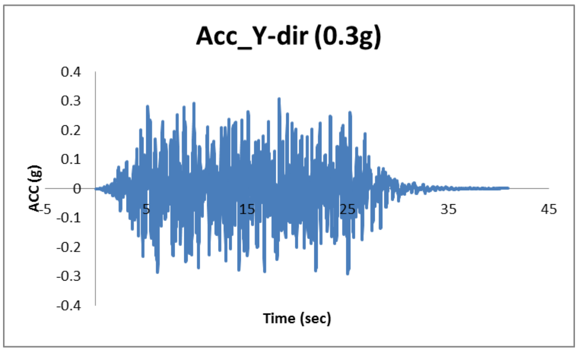

Fig. 4. Input seismic acceleration

3. Compare to the response about linear/non-linear seismic base isolation system

The natural frequency, the shear force of the lower of the structure, and the floor response spectrum results on a non-isolated structure and isolated structure (equivalent linear) were summarized by a time history analysis. The natural frequency of the non-isolated structure was 0.3375sec and the isolated structure was 1.154sec and this showed an increase about 242%. The results of the shear force of the lower of the structure from the analysis was compared and shown in Fig 5.

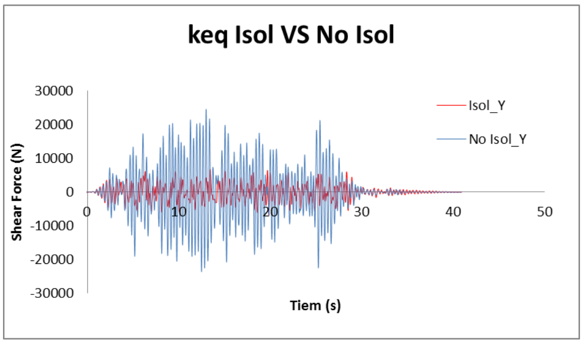

Fig. 5. The shear force of lower point of the structure

An apparent reduction of shear force was shown, as can be confirmed from the graph. In addition, the shear force showed a maximum decrease about 89%. The floor response spectrum of the structure was compared and shown in Fig 6.

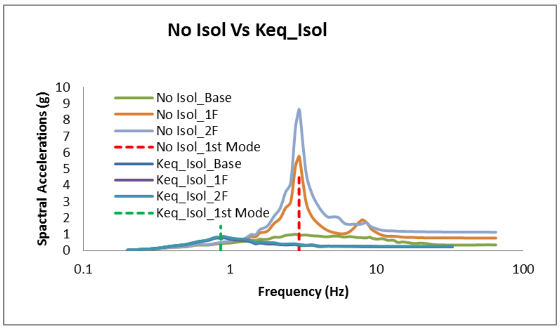

Fig. 6. The floor response spectrum of a structure

Because of an isolated system was applied to the structure, reduction of the floor response spectrum was found in the isolated structure. The increase response of the non-isolated structures in 3Hz was considered because of the first mode frequency (2.963Hz) of the structure. In addition, the floor response spectrum showed no significant differences in each layer caused by application of the seismic base isolation system.

The shear force of the lower point of the structure result from the analysis in consideration of linear/non-linearity of structure was compared and shown in Fig 7.

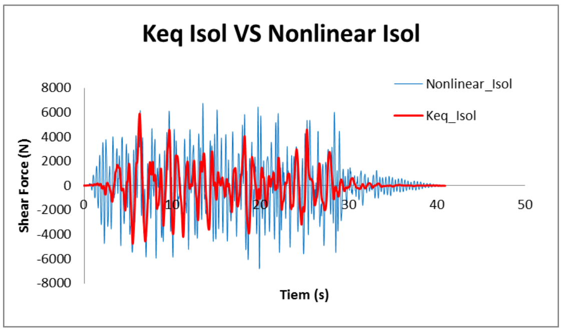

Fig. 7. The shear force of lower point of the structure in consideration of linear/non-linearity of structure

Because of the non-linear characteristics, the graph does not appear to be smooth, but the value of maximum and minimum, the overall shape of graph can be sure that it is displayed very similar to the results obtained by analyzing the equivalent linear.

The floor response spectrum of the structure result from the analysis in consideration of the linear/non-linearity of isolated structure was compared and shown in Fig 8.

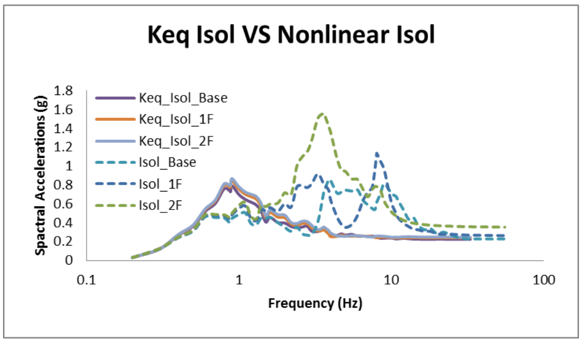

Fig. 8. The floor response spectrum of the structure in consideration of linear/non-linearity of structure

The similar results were observed in a previous about 0.6Hz, but shows different of results on remaining region. The influence of the nonlinear isolation system was increased in the hi-frequency domain. In addition, in the case of considering the nonlinearity of the isolation system, the values of floor response spectra appeared to have a different of responses in each floor. The non-linearity of the isolated structure was considered, because of a more reliable floor response spectrum of a seismic base isolation system.

4. Conclusions

In this study, the floor response spectrum of the seismic base isolation system by the non-linear effect of the rubber isolator was analyzed. As a result, the influence of the non-linear isolated system was increased in hi-frequency domain. In addition, each floor exhibited a more different of responses compared with the equivalent linear model of the isolated structure. The non-linearity of the isolation system of the structure was considered, because of a more reliable assessment of integrity of equipment at each floor of seismic base the isolation system.

Acknowledgement

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[1] Song, Sung-Hoon Cha, Myung-Kun Ryu, Hong-Sik Oh, Sang-Hoon Lee, Sang-Ho, Dynamic Response Characteristics of the Base-Isolated Structure for Shake Table Test , Journal of the Korean Society of Civil Engineers, Korean Society of Civil Engineers, Vol.26, p. 21, 2010.04