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Analysis of Bi-directional Effects on the Response of a Seismic Base Isolation System

Hyung-Kui Park [a*], Jung Han Kim [a], Min Kyu Kim [a], In-Kil Choi [a]
[a]*Integrated Safety Assessment Division, Korea Atomic Energy Research Institute, 989-111 Deadeok-daero, Deajeon,305-353, Republic of Korea*
[*]*Corresponding author: hyungkui@kaeri.re.kr*

1. Introduction

The floor response spectra (FRS) of the structure should be sought for evaluating of the integrity of the internal equipment. The floor response spectrum depends on the height of the floor of the structure. Also FRS depends on the characteristics of the seismic base isolation system such as the natural frequency, damping ratio. In the previous study, the floor response spectrum of the base isolated structure was calculated for each axis without considering bi-directional effect. However, the shear behavior of the seismic base isolation system of two horizontal directions are correlated each other by the bi-directional effects. If the shear behavior of the seismic isolation system changes, it can influence the floor response spectrum and displacement response of isolators. In this study, the analysis of a bi-directional effect on the floor response spectrum was performed.

2. Analysis Model

2.1 Analysis Model

The seismic isolation system was represented as the single degree of freedom system in which the superstructure is rigid body and isolator is spring element. Example single degree of freedom system was assumed as shown in Fig. 1. Mass of single degree of freedom is 20.35 kN, and has a natural period of 2 sec.

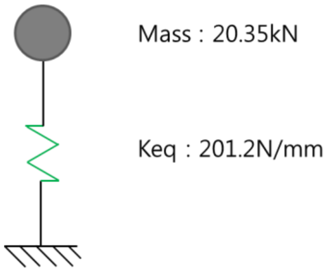


Fig. 1. The Single degree of freedom system

A lead-rubber bearing (LRB) isolator was used for this study. The modeling parameters of the LRB are listed in Table1.

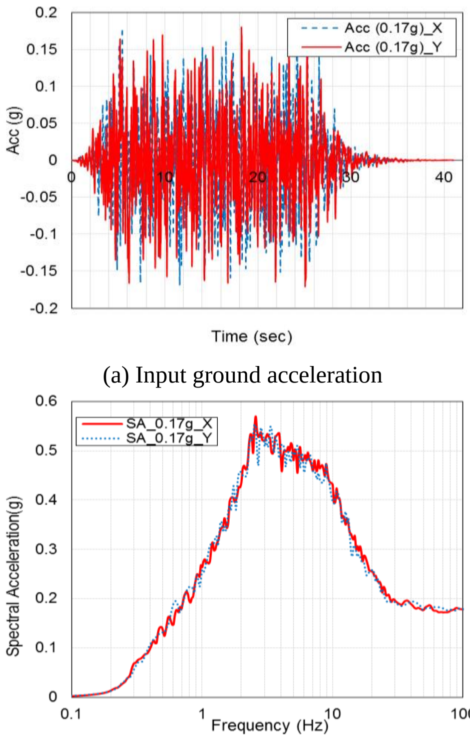
Table I: The major specifications of the rubber bearing isolator (Unit: N/mm)

Total Thickness of Rubber	60mm
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)	4089N
Equivalent stiffness (Keq)	201

Commercial software SAP2000 was used for an analysis of the floor response spectra. A nonlinear response history analysis performed considering the non-linearity of the LRB. A bi-linear model based on rate-independent plasticity theory can be used to characterize the bi-directional behavior of LRB.

2.2 input ground acceleration

The ground acceleration was generated on the basis of the RG 1.60. Input ground acceleration was adjusted to fit the design displacement of the LRB. The ground acceleration was used for an analysis of the FRS. The generated ground motion is as shown in Fig. 2. To analyze the bi-directional effect, two situations will be compared, one where ground acceleration is applied in a one-direction and the other case where ground acceleration is applied in a two-direction manner.



(a) Input ground acceleration

(b) Spectral acceleration
Fig. 2. Input ground motion

3. The response comparison with seismic base isolation system considering bi-directional effect.

The results of the shear force of the seismic base isolation system from the analysis were compared as shown in Fig. 3.

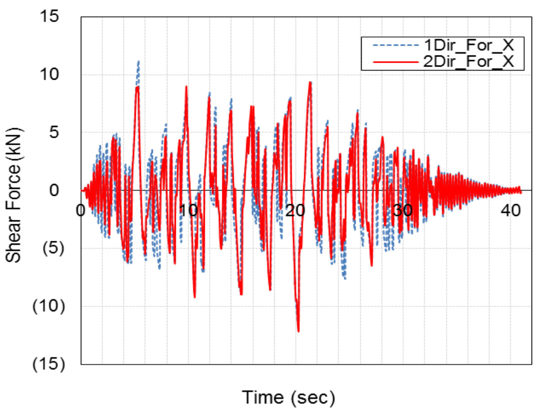


Fig. 3. The results of the shear force of the seismic base isolation system

The maximum shear force of the seismic base isolation system was similar at about 12kN. However, it was observed that when ground acceleration is applied in a two-directional manner, the overall shear force is more reduced than when ground acceleration is applied in a one-directional manner. It seems that this is due to the fact that when the ground acceleration is put on two-directions(X, Y), the overall shear force is decreased because of the bi-directional effect of the seismic base isolation system.

The results of the displacement-shear force for a seismic base isolation system from the analysis were compared and are shown in Fig. 4.

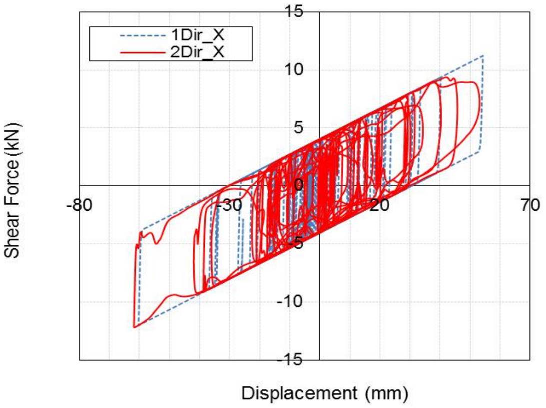


Fig. 4. The results of the displacement-shear force of the seismic base isolation system

As described above, the maximum shear force of the isolator was almost the same. However, it was observed that when ground acceleration is applied in a two-directional manner, the cumulated energy dissipated area is more reduced than when ground acceleration is applied in a one-directional manner. This can be determined as a result of the bi-directional effects of the seismic isolation system. The results of the floor response spectrum of the seismic base isolation system from the analysis were compared and are shown in Fig. 5.

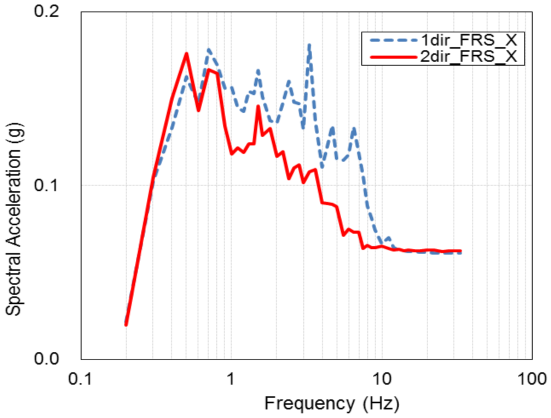


Fig. 5. The results of the floor response spectrum of the seismic base isolation system

Owing to the decreased shear force, the floor response spectrum is more reduced in a two-directional than in one-directional. On the other hand, the result of the two-directional is able to confirm an increase of 11.3% in the low frequency region.

4. Conclusions

In this study, the response of the seismic base isolation system based on the bi-directional effects was analyzed. By analyzing the time history result, while there is no alteration in the maximum shear force of seismic base isolation system, it is confirmed that the shear force is generally more decreased in a one-directional that in a two-directional in most parts. Due to the overall decreased shear force, the floor response spectrum is more reduced in a two-directional than in a one-directional. However, the FRS of the two-directional is able to confirm an increase of 11.3% in the low frequency region. It appears to be a result of a bi-directional effect of the seismic base isolation system. Therefore, a bi-directional effect of the seismic base isolation system is required to draw the conclusion of the floor response spectrum.

Acknowledgement

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