Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 25-26, 2012

Seismic Response of Base Isolated Auxiliary Building with Age-related Degradation

Junhee Park [a*], Young-Sun Choun [a], In-Kil Choi [a]
[a] *Korea Atomic Energy Research institute, 1045 Daedeok-daero, Yuseong, Daejeon, 305-353*

[*] *Corresponding author:jhpark78@kaeri.re.kr*

1. Introduction

The aging of an isolator affects not only the mechanical properties of the isolator but also the dynamic properties of the upper structure, such as the change in stiffness, deformation capacity, load-bearing capacity, creep, and damping. Therefore, the seismic response of base isolated structures will change with time. The floor response in the base isolated nuclear power plants (NPPs) can be particularly changed because of the change in stiffness and damping for the isolator. The increased seismic response due to the aging of isolator can cause mechanical problems for many equipment located in the NPPs. Therefore, it is necessary to evaluate the seismic response of base isolated NPPs with age-related degradation.

In this study, the seismic responses for a base isolated auxiliary building of SHIN-KORI 3&4 with age-related degradation were investigated using a nonlinear time history analysis. Floor response spectrums (FRS) were presented with time for indentifying the change in seismic demand under the aging of isolator.

2. Time-dependent material property of isolator

2.1 Stiffness

According to the degradation state of previous base isolated structures (e.g., iron railway viaduct in Melbourne and Pelham-Bridge in Great Britain), it was shown that the fracture strength and the elongation of rubber were reduced and the stiffness was increased.

It was reported through a finite element analysis for a high damping rubber bearing that the stiffness of the aged isolator increased about 20% because of the hardening of the rubber [1].

2.2 Damping

The damping capacity of an isolator with age-related degradation has been evaluated using an accelerated heat test [1]. Itoh et al. showed that a damping ratio with time was about 5%, as shown in figure 1. It can be also observed that the stiffness variation rate is mainly caused by the age-related degradation of isolator

Figure 1 shows the horizontal stiffness and damping ratio of high damping rubber (HDR) over time. The difference in the stiffness and damping ratio with time is increased.

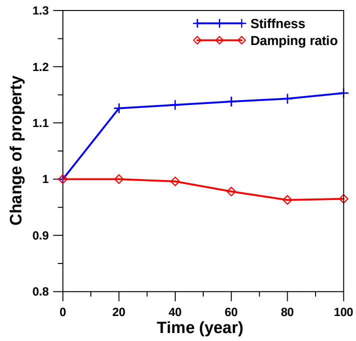

Fig. 1. Stiffness and damping ratio of HDR bearing over time [1]

3. Analytical model

The auxiliary building of SHIN-KORI 3&4 was chosen as an analytical model because many equipment related to the operation of NPPs are located in that building.

The auxiliary building was represented by lumped-mass stick models in the seismic analysis. The lumped-mass stick models having different eccentricities between mass centers and rigidity centers are developed, as shown in figure 2. The mass of each floor includes the mass of walls, slabs, columns, and heavy equipment.

For the design of the isolator, the target frequency is decided as 1Hz. The horizontal stiffness of each isolator was decided as 33711.92kN/cm considering the weight of the auxiliary building (about 330,000tonf) and target frequency. It was assumed that the vertical stiffness was decided as 1000 times the horizontal stiffness. The isolators were modeled using a nonlinear link of SAP2000, as shown in figure 2.

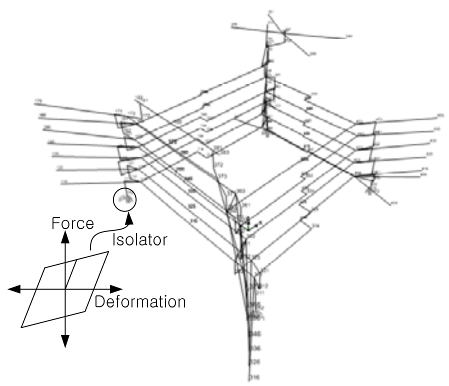

Fig. 2. Analytical model for Auxiliary building (SKN 3&4)

4. Input ground motion

Four earthquakes with different frequency contents were selected to evaluate the seismic response for the base isolated structure according to the frequency content of the earthquakes. Figure 3 shows the spectral acceleration for the seismic analysis. NRC and UHS represent the design spectrum of NRC Reg. guide 1.60 and uniform hazard spectrum (UHS) for the Korean NPPs, respectively. Chi-chi and Sylmar90 are real earthquakes recorded in Taiwan and the USA.

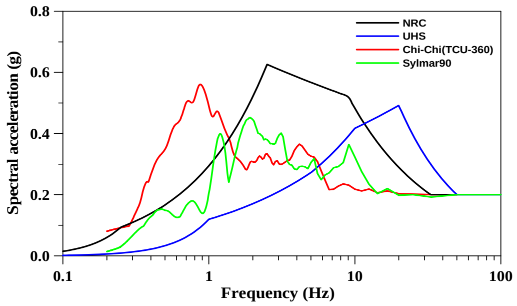

Fig. 3. Spectral acceleration of input ground motion

5. Results and Discussions

5.1 Modal analysis

The increased stiffness of the isolator from age-related degradation changes the dynamic property of the base isolation system over time. Under the design life of NPPS, the natural frequency of the auxiliary building with the aging of isolator increased from 1Hz to 1.065Hz. From the modal analysis of the base isolated system, it was observed that the natural frequency was rapidly changed for 20 years, and then the increase speed slows down.

5.2 Floor response spectrum (FRS)

Except for the chi-chi earthquake with a low predominant frequency, the zero period acceleration of the analytical model was decreased dramatically compared to the fixed system. However, the age-related degradation of the isolators can lead to a change in the FRS, as shown in figure 4.

To identify the change in spectral acceleration due to the age-related degradation of the isolator, the ratio of spectral acceleration was presented, as shown in figure 5. From the results, it was observed that the ratio of spectral acceleration is increased about 20% from 1Hz to 3Hz, while the ratio of spectral acceleration was decreased from 3Hz.

It can be concluded that the equipment with low frequency (below 3Hz) has an effect on the age-related degradation of isolator, but the equipment with high frequency (over 10Hz) has little effect on the aging of the base isolator.

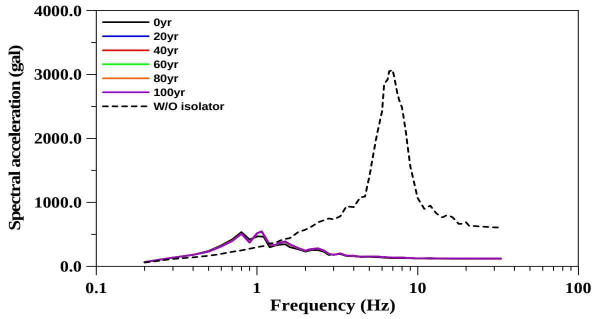

Fig. 4. FRS over time (UHS)

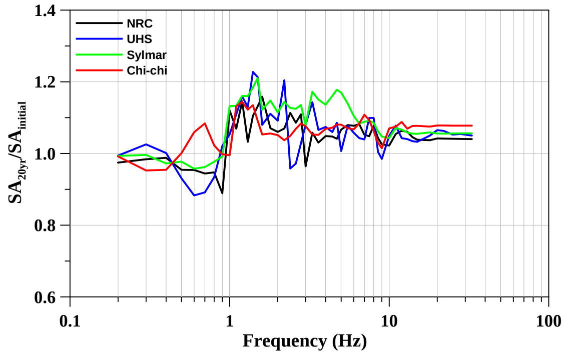

Fig. 5. The change of spectral acceleration by age-related degradation

6. Conclusion

The seismic response of the base isolated system can be changed by age-related degradation. In this study, a seismic analysis of an auxiliary building was carried out to evaluate the seismic response of structure through the aging of isolator.

When an isolator is designed, the target frequency should be defined considering the change in seismic demand due to the aging of isolator because the frequency at which the maximum spectral acceleration occurs changes according to the target frequency.

Because the degradation of the isolator rapidly progress by 20years, the inspection of isolator should be carefully conducted by that time for proper maintenance.

Acknowledgement

This work was supported by the Nuclear Research & Development of the Korea Institute of Energy Technology Evaluation and Planning(KETEP) grant funded by the Korea government Ministry of Knowledge Economy (No. 2011T100200080)

REFERENCES

[1] Itoh, Y, Gu, H., Satho, K. and Yamamoto, Y., “Long-term Deterioration of High Damping Rubber Bridge Bearing,” Structural Eng./Earthquake Eng. JSCE, Vol. 23, No.2, 215-227, 2006.