Floor Response Spectra of a Base Isolated Auxiliary Building in Different Temperature Environments

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1. Introduction

The seismic behavior of upper structure in a base isolated structure is closely related with the horizontal stiffness and damping of isolator. The property of lead rubber bearing is influenced by the material of isolator such as a rubber, a steel plate and lead. Among the materials of isolator, the rubber is attacked by oxygen, temperature, light, dynamic strain and liquids [1].

In the nuclear power plants (NPPs), the base isolated structures can be exposed to various degradation factors for a long time, therefore the degraded isolators can affect floor response for the equipment. Therefore, it is necessary to investigate the aging effect of degradation factors and to evaluate the seismic response of base isolated NPPs with age-related degradation.

In this study, the seismic responses for NPPs using high damping rubber bearing with age-related degradation in different temperature were investigated by performing a nonlinear time history analysis. The floor response spectrums (FRS) were presented with time in different temperature environments.

2. Temperature-dependency of rubber

In this study, the temperature environment was assumed as 15℃ and 25℃ for evaluating the seismic response of isolated NPPs in different temperature.

The temperature-dependency of properties for high damping rubber bearing (HRB) reported by Itoh et al.[2] were used to perform the nonlinear time history analysis for the isolated NPPs with age-related degradation as shown in Fig. 1.

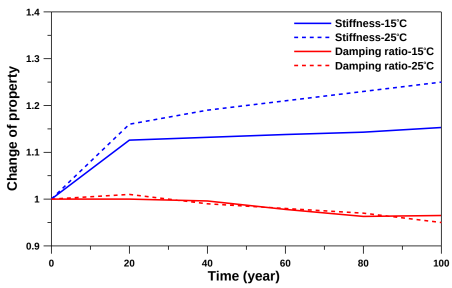


Fig. 1. Change of property for HRB in different temperature

It was reported that the ultimate capacity of aged isolator is decreased with time [3]. Therefore it was represented that the horizontal stiffness of HRB increased with temperature while the damping ratio of isolator showed a little change with temperature. From the fig 1., the horizontal stiffness of HRB at 25℃ increased about 25% while that at 15℃ was increased about 14%.

3. Seismic analysis of auxiliary building

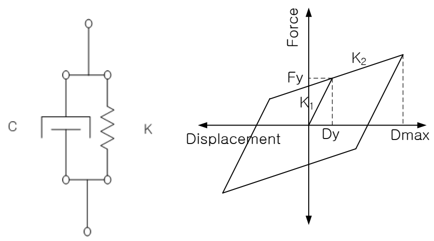
3.1 Input ground motion

As an input motion, four acceleration response spectrums with different frequency contents were selected to evaluate the seismic response for the base isolated structure. NRC Reg. guide 1.60, uniform hazard spectrum (UHS) for the Korean NPPs, Chi-chi and Sylmar90 were used.

3.2 Analytical model

In this study, the HRB was used to decrease the displacement of isolator under seismic load. The stiffness of HRB was defined considering the target frequency (1Hz). It was assumed that the damping ratio of HRB equals to 20% at initial condition.

The AUX of SHIN-KORI 3&4 was chosen as an analytical model because many of equipment related to the operation of NPPs are located in that building. The AUX were represented by lumped-mass stick models for the seismic analysis. The mass of each floor includes the mass of walls, slabs, columns, and heavy equipment.



(a) Analytical model (b) Hysteretic model
Fig. 2. HRB model for SAP 2000

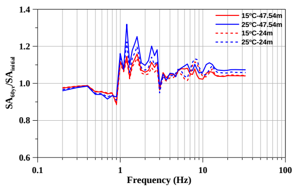
3.3 Results

The deformation of isolated NPPs is originated at the level of isolator under seismic load. Therefore, if the properties of isolators change due to the age-related degradation, the natural frequency of isolated NPPs will be changed. From this modal analysis result, after 60 years, it is represented that the natural frequency of example models is 1.094Hz at 25℃ and 1.065Hz at 15℃ because the horizontal stiffness of HRB increased more greatly at a higher temperature.

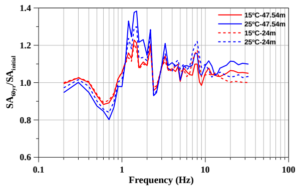
Fig. 3 shows the ratio of spectral acceleration for the NRC ground motion between initial model and 60 year model at different floor. At high temperature, it is observed that the change of spectral acceleration is high due to the aging of isolator.

Because the stiffness of isolator is increased by the aging, the change of FRS at 47.54m is higher than that at 24m. And the FRS of the AUX correlated with temperature degree, as shown in fig. 3.

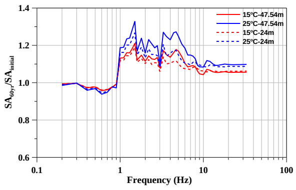
From the fig. 5, After 60 years, the floor response spectrum for the AUX at 15℃ was increased by about 20% while it was increased by up to 40% at 25℃ within 1Hz and 2Hz.



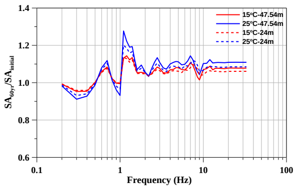
(a) NRC



(b) UHS



(c) Sylmar90



(d) Chi-chi

Fig. 3. The change of spectral acceleration for AUX in different temperature

4. Discussion

The FRS was changed by the effect of degradation of HRB as shown in fig 4. 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.

The seismic capacity for the equipment located in NPPs can be affected by the increased FRS due to the degradation of HRB. In this study, the seismic fragility for the cabinet in AUX was conducted by using the EPRI method [4].

Fig 5 shows that the mean fragility curves for the cabinet in the AUX with age-related degradation of HRB. The solid line presents the fragility curve of the cabinet when the HRB were installed in AUX. The dashed line presents that of cabinet with the aging of HRB after 60 years. It was showed that the cabinet at 60 years is more vulnerable than at 0 year because the RRS_c was increased with the horizontal stiffness of isolators by the aging.

The seismic capacity for the cabinet located in the AUX with the aging of HRB. Because the RRS_c and the uncertainty of FRS were changed by the aging of the HRB, it was observed that the high confidence low probability failure (HCLPF) for the example cabinet was decreased about 38% by the aging of HRB.

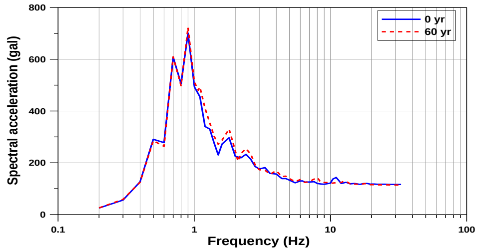
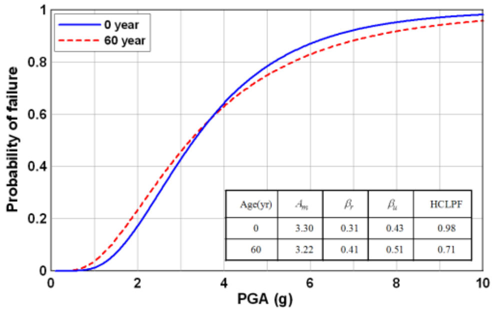


Fig. 4. The FRS of AUX under the NRC motion



Age(yr)	A_m	β_r	β_u	HCLPF
0	3.30	0.31	0.43	0.98
60	3.22	0.41	0.51	0.71

Fig. 5. The mean fragility curves for cabinet in AUX with aging of isolator under the NRC motion

5. Conclusion

The degradation of HRB is found to be particularly sensitive to the ambient temperature. The increase of HRB stiffness leads to the increase of FRS it was observed that the seismic demand for equipment located in the AUX was changed. Therefore it is required that the seismic evaluation for the isolation system (e.g. isolators, equipment located in isolated structure) is performed considering the temperature environments.

From the seismic fragility analysis, the seismic capacity of cabinet was affected by the degradation of HRB. Therefore the isolators in the isolated buildings should be carefully designed and manufactured considering the degradation during the life time.

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)

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