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Dynamic analysis of LRB seismic isolator for nuclear power plant

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ABSTRACT

This paper evaluated the earthquake reduction effect using a seismic isolator as a method to improve the seismic performance of a nuclear power plant. After the disaster of the great earthquake in eastern Japan, interest in the earthquake resistance of nuclear power plants is at its peak, and a seismic isolator must be considered when a nuclear power plant is constructed in an area prone to strong earthquakes. In this sense, this paper described results from the earthquake analyses integrating seismic design and the seismic isolation system to improve the export competitiveness of the export version of the nuclear power plants developed domestically. The seismic isolator used is LRB(Lead Rubber Bearing), which is often used domestically.

1. INTRODUCTION

Nuclear power plants have traditionally attempted to secure the stability of the structure from earthquakes through seismic design. However, studies on the application of seismic isolators have been actively conducted with the trend of increasing the seismic load of the design of nuclear power plants and the frequency of strong earthquakes. France has already constructed a nuclear power plant with a seismic isolator in the 1980s, and the power plant is in commercial operation. A research reactor with a seismic isolator is currently under construction. In addition, Japan has prepared a design code for the application of seismic isolation design to nuclear power plants, and the United States is in the process of drafting NUREG-Draft to make seismic isolation regulation guidelines. With such international trends, and in an attempt to secure the exporting competitiveness of nuclear power plants, studies on applying seismic isolators to exporting nuclear power plants are being conducted domestically. Therefore, a seismic isolation system technology capable of withstanding the maximum ground acceleration of 0.5g along with a conventional seismic design capable of withstanding the ground acceleration of 0.3g are being developed. Therefore, earthquake analyses related to the seismic isolators are being developed in

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order to apply them to nuclear power plants. These isolators and the seismic force reduction effect of the developing seismic isolators are being evaluated. The used seismic isolator is lead rubber bearing (LRB).

2. EARTHQUAKE ANALYSIS MODEL

The seismic isolation of a nuclear power plant is scheduled to be applied to the mat foundation at the lower part of the containment and auxiliary buildings as a NI(Nuclear Island) sector. Fig. 1 shows the concept diagram of the seismic isolation system application of exporting nuclear power plants. The wall section in Fig. 1 is a moat structure that enforces a hard stop when a certain amount of strain occurs to prevent the fall of the upper structure. The seismic isolator is installed at the moat structure. The total weight of the supper structure is approximately 440 thousand tons and the area of application of the seismic isolator is approximately 104m × 84m. The LRB seismic isolator was designed along with the characteristics of the supper structure and the target period was set to be 2 sec. The results are listed in Table 1. 1000 LRB isolators are in the entire seismic isolation sector, and the design displacement is ±130 mm with the outer diameter of isolator as 1,1000 mm.

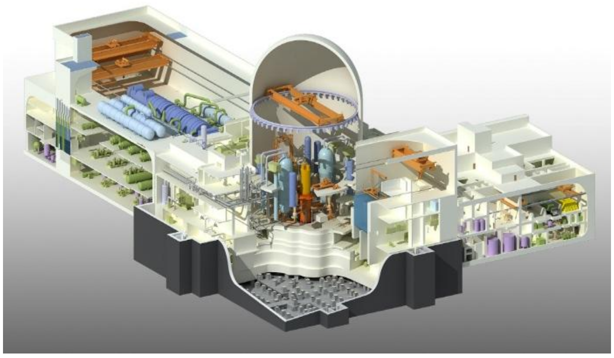


Fig. 1 Concept diagram of NPP seismic isolation system (KEPCO-E&C, 2012)

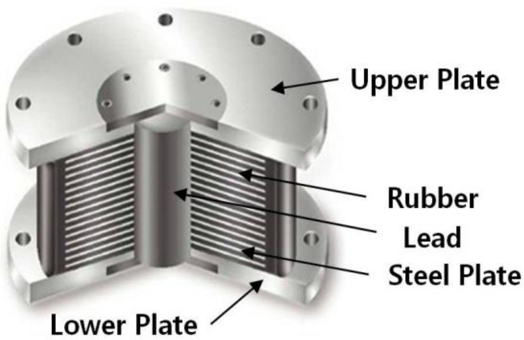


Fig. 2 LRB cross section

Table 1 LRB design properties of seismic isolator

Target period (sec)	Displacement (mm)	Outer diameter (mm)	Design bearing (MPa)	Primary rigidity (kN/m)	Secondary rigidity (kN/m)	Number of supports
2.0	±130	1,100	13	27,374	2,106	1,000

The analysis model for earthquake analysis was modeled with respect to the NI sector and the program used was SAP2000 Ver.15. Considering the earthquake analysis time, the mat foundation of the supper structure was separated into 540 solid

components and the upper part of the mat foundation was modeled as a concentrated mass.
The time history acceleration(based on PGA=1g) used in the seismic analysis of exporting nuclear power plants was scale adjusted to PGA=0.5g to be used as the input earthquake. The time interval of the artificial seismic waves was 0.005sec, resulting in the total sustainment time of 20.48 sec, and they were statistically independent with respect to the three directions.

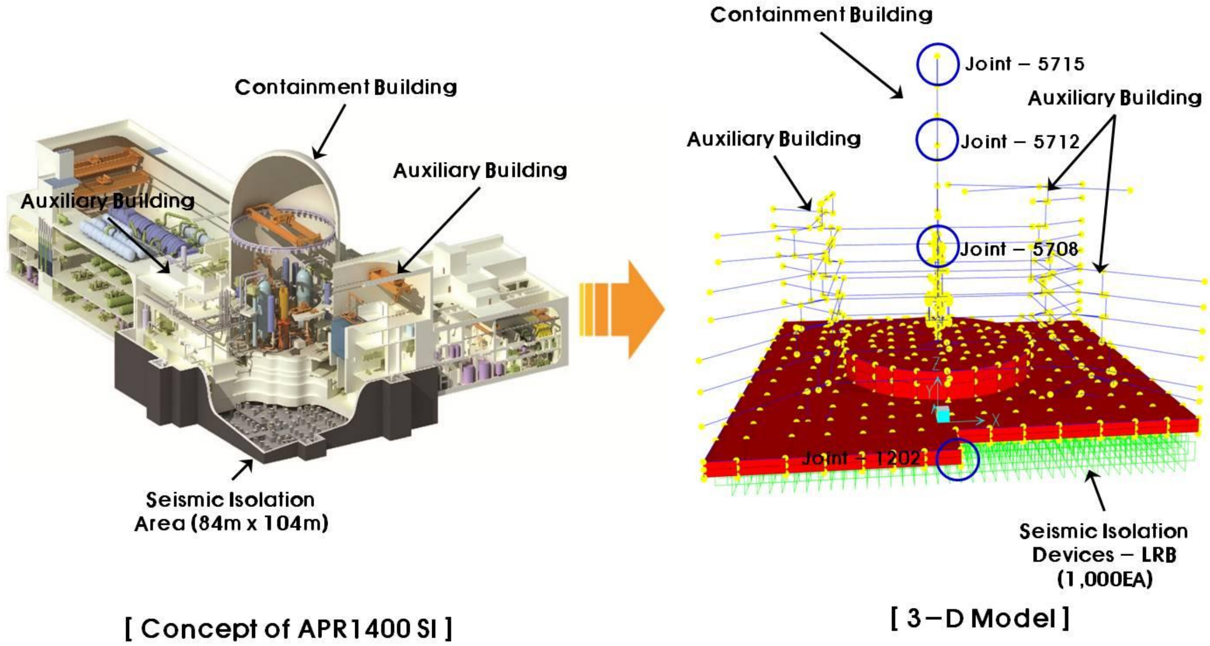
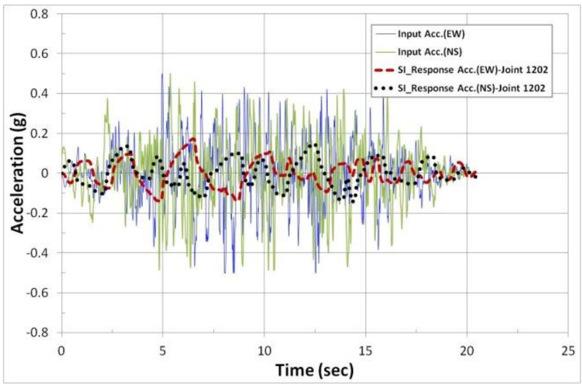


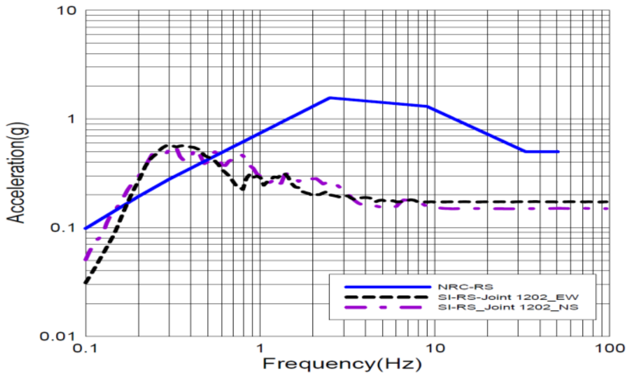
Fig. 3 Concept diagram of NPP seismic isolation system and 3-dimensional analysis model

3. EARTHQUAKE ANALYSIS RESULT

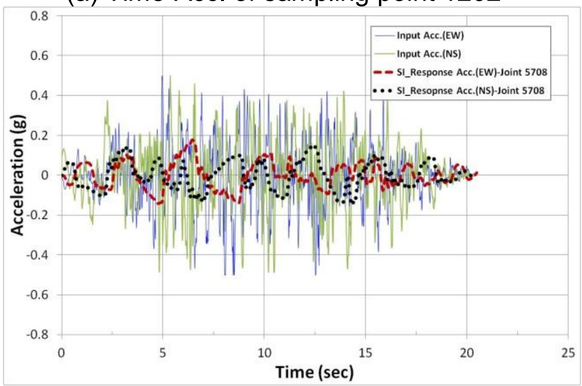
Fig. 4 is the earthquake analysis result of the seismic isolation system. The acceleration time history curve, with respect to the east-west(EW) direction and north-south(NS) direction, and the response spectrum at the major locations, the 4 sampling points illustrated in Fig. 3, were compared. As illustrated in the figure, the input seismic waves with respect to the two directions are significantly reduced at each sampling point. However, this yielded results larger than the NRC Reg. Guide, which constitutes the standard, in the low frequency region. Therefore, the detailed review on the equipment/structure or the target period of the entire seismic isolation system should be adjusted so that the design satisfies the standard response spectrum in every region.
The maximum acceleration and seismic force reduction results at each sampling point are listed in Table 3. The minimum acceleration in both directions was observed at the sampling point 1202, which is directly above the seismic isolator, and the trend of increasing acceleration in approaching the upper part was observed, but the relative difference was not significant. The seismic force was reduced by a maximum of 70.2% (sampling point 1202-NS) and a minimum of 61.6% (sampling point 5715-EW).



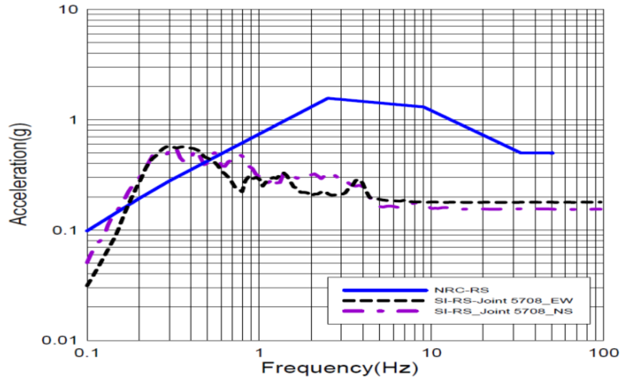
(a) Time-Acc. of sampling point 1202



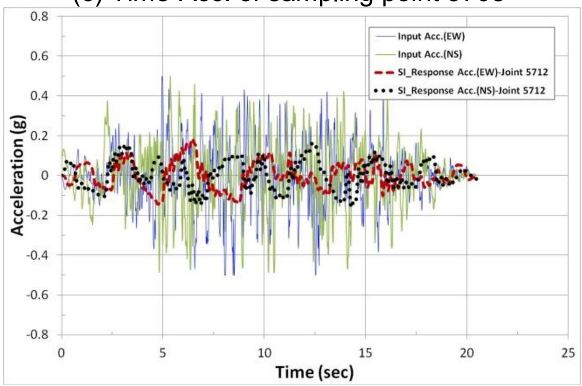
(b) Response spectrum of sampling point 1202



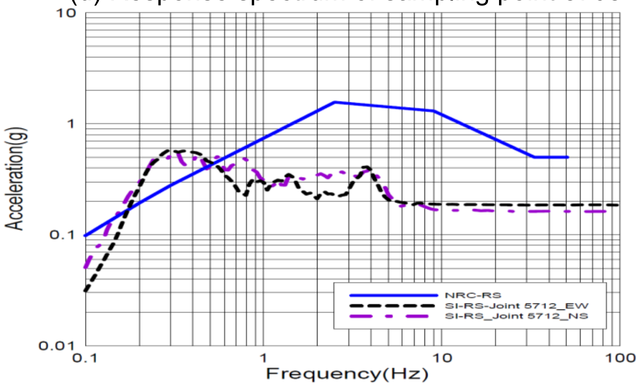
(c) Time-Acc. of sampling point 5708



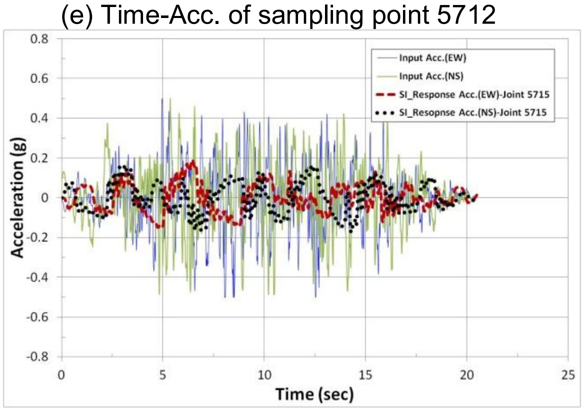
(d) Response spectrum of sampling point 5708



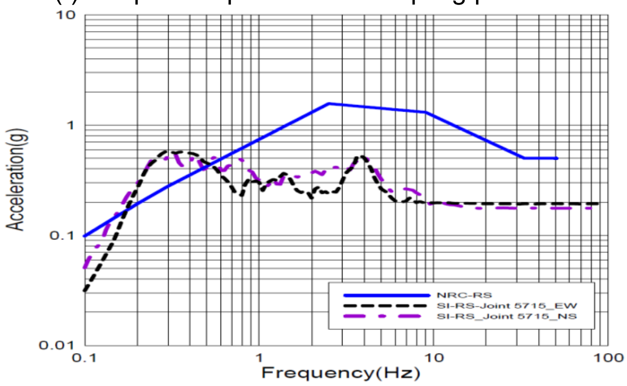
(e) Time-Acc. of sampling point 5712



(f) Response spectrum of sampling point 5712



(g) Time-Acc. of sampling point 5715



(h) Response spectrum of sampling point 5712

Fig. 4 Earthquake analysis result of LRB seismic isolator

Table 3 The maximum accelerations and reduction effects at the major panel points (Unit :g)

Input acceleration		Point 1202		Point 5708		Point 5712		Point 5715	
EW	NS	EW	NS	EW	NS	EW	NS	EW	NS
0.5		0.172	0.149	0.178	0.154	0.185	0.162	0.192	0.175
Reduction effect (%)		65.6	70.2	64.4	69.2	63.0	67.6	61.6	65.0

4. CONCLUSIONS

This paper analyzed earthquakes with respect to LRB seismic isolator prototypes that will be applied to the exporting nuclear power plants, and described the response acceleration and response spectrum at major points. The target period of the seismic isolation applied region is 2 sec, and the input earthquake motion is the artificial earthquake wave used in the seismic analysis of exporting nuclear power plants with a maximum acceleration of 0.5g. The analysis result yielded 70.2% seismic force reduction directly above the seismic isolator and 61.6% seismic force reduction at the upper part of the containment building. Therefore, the LRB seismic isolator prototype developed in this research was determined to be adequate to be applied to the seismic isolation system of the exporting nuclear power plants in the future. However, more detailed review is required because the response spectrum from a portion of the low frequency region was larger than the design response spectrum.

ACKNOWLEDGMENT

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REFERENCES

US-NRC (2012), “Technical considerations for seismic isolation of nuclear facilities,” NUREG-Draft.

JNES (2012), “Technical review guidelines for structures with seismic isolation,” Japan Nuclear Energy Safety Organization.

Computers & Structures (2010), SAP2000 Ver.15.0.1 user's manual.