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Experimental Study on 3-Directional Reduction Effectiveness of Main Control Room of N.P.P using 3-Dimensional Isolation System

K. J. Lee,a K. W. Ham,a Y. P. Suh,a
a Environment & Structural Lab., KEPRI, 103-16, Munji, Yuseong, Daejeon, Leekj@kepri.re.kr

1. Introduction

Main control room of nuclear power plant operates many important N.P.P facilities such as NSSS(Nuclear Steam Supply System), so it is highly recommended to secure seismic safety of main control room during and after earthquakes. A number of isolation systems installed between equipment and foundation have been widely studied[1,2]. We applied 3-D isolation systems which are consist of FPS(Friction Pendulum System), Air Spring and Damper. FPS is resistant to horizontal motion and Air Spring is resistant to vertical motion and viscous damper is resistant to rocking motion and excessive displacements.

In this study, we designed two types of main control floor systems (Type I, Type II) and a number of shaking table tests with and without 3-D isolation system were conducted to evaluate floor isolation effectiveness.

2. Shaking Table Test Procedure

2.1 structural and geometric features

Test specimen is a PCS cabinet which is installed in ULJIN 1st ,2nd main control room (Fig. 1). During shaking table test, electric parts of the cabinet are removed and the weight of PCS cabinet only is 400kgf.

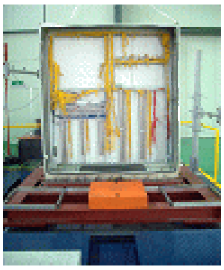


Figure 1. Cabinet


Figure 2. FPS

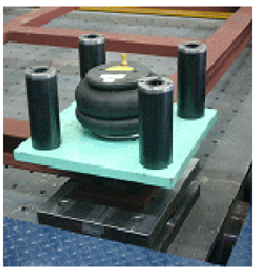


Figure 3. Air Spring

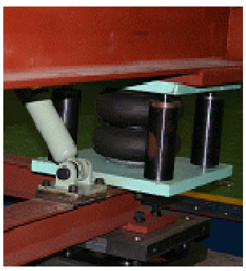


Figure 4. Damper

Four identical 3-D isolation systems were mounted beneath the bare frame model under OBE, SSE horizontal and vertical input motions. The properties of 3-D isolation systems are summarized in Table 1 and Fig 2~4 show the schematic view of 3-D isolation system.

Table 1. Specification of 3-D isolation system

FPS	Natural Frequency	0.5Hz
	Radius of curvature	0.99m
Air Spring	Natural Frequency	2.0Hz
	Vertical weight capacity	700kgf/ea
Viscous Damper	Damping ratio	15%
	Damping Coefficient	15,000N·sec/m

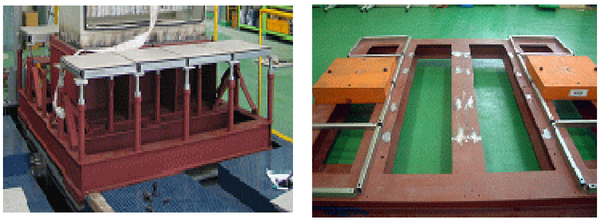

(a) Floor system Type I (b) Floor System Type II
Figure 5. Two different types of Floor System

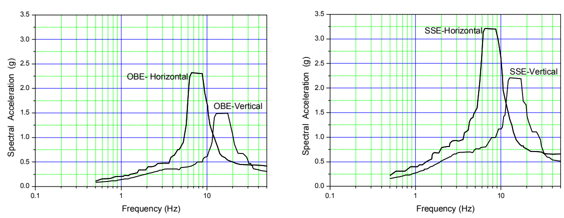
Fig. 5 shows two different types of floor system (Type I, Type II) which was designed to access effectiveness of seismic vibration reduction. Geometric features of two floor systems are digested in Table 2.

Table 2. Floor system dimension

Type	W × D × H (m)	Weight	Frame(mm)
Type I	2.5 × 2.5 × 0.8	2tonf	H-200×200×8×12
Type II	2.5 × 2.5 × 0.2	2tonf	H-200×200×8×12

2.2 Input motion

Fig. 6 shows floor response spectrum of OBE, SSE at 144ft. Note that the peak acceleration responses of horizontal earthquake motion are distributed about 6-8 Hz frequency range, whereas vertical design ones are in higher frequency range(15-16Hz).



(a) OBE (b) SSE
Figure 6. Input motion (Floor Response Spectra)

2.3 Shaking Table Tests

In order to acquire the response of the cabinet, 3 horizontal accelerometers were attached at the lateral surface of the cabinet (top, mid, btm) and 2 vertical ones were attached on the both sides of the cabinet bottom (left, right)

3. Test Results and discussion

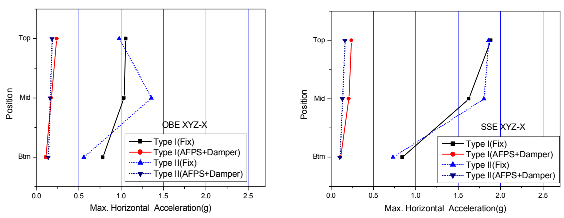
3.1 Acceleration Comparison

The measured maximum floor accelerations for bare frame and isolated model under strong ground motions are presented in Table 3. With the provision of 3-D Isolation system, a significant reduction effect was seen under OBE & SSE.

Table 3. Maximum floor acceleration

Input Motion (Max. Acc, g)	Hori.	Top		Mid		Btm	
	Vert.			Left		Right	
		W/O	With	W/O	With	W/O	With
OBE Hori. (0.554)	Type I	1.055	0.240	1.035	0.175	0.785	0.111
	Type II	0.977	0.184	1.357	0.162	0.560	0.140
SSE Hori. (0.753)	Type I	1.887	0.242	1.626	0.210	0.841	0.114
	Type II	1.859	0.165	1.804	0.134	0.732	0.104
OBE Vert. (0.389)	Type I			0.461	0.211	0.433	0.157
	Type II			0.452	0.182	0.431	0.134
SSE Vert. (0.734)	Type I			0.768	0.326	0.721	0.262
	Type II			0.784	0.303	0.737	0.249

Fig. 7 shows maximum horizontal acceleration response of the cabinet with respect to height. As it was seen in Table 3, there was a little difference between OBE and SSE whereas Type II shows 10% more acceleration reduction effect compared to Type I.

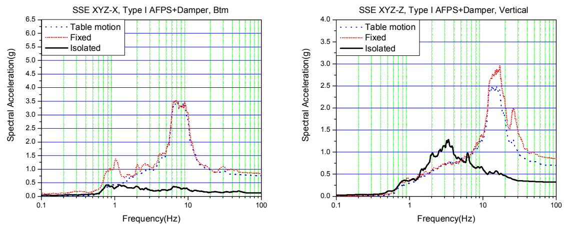


(a) OBE (b) SSE

Figure. 7 Max. acceleration W.R.T cabinet height

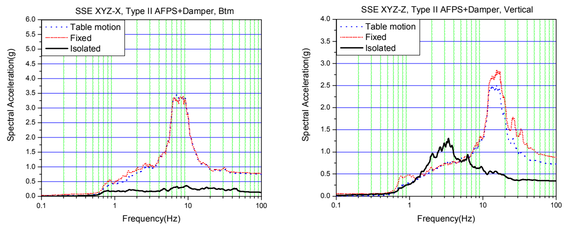
3.2 Response Spectrum

Acceleration response spectra at the bottom of the cabinet are presented in Fig. 8~9. Large acceleration reduction effect was seen in long periodic input motions (OBE, SSE). And Type II showed 20% less max response spectral acceleration. In vertical direction, there was an obvious predominant frequency drift(3.0Hz) to the air spring natural frequency(2.0Hz), whereas there was no one in horizontal direction.



(a) Horizontal (b) Vertical

Figure 8. Acceleration Response Spectrum (SSE, Type I)



(a) Horizontal (b) Vertical

Figure 9. Acceleration Response Spectrum (SSE, Type II)

4. Conclusion

To evaluate floor isolation effectiveness of 3-D isolation system, several seismic shaking table tests with and without isolation system were conducted. As a result of tests, both types have showed large reduction effect according to input earthquake signals, but Type II showed large acceleration reduction effect compared to Type I. And it showed large seismic reduction effect when subjected to long periodic earthquake motions. Also there was an obvious predominant frequency drift effect to the vertical isolation natural frequency in vertical direction.

ACKNOWLEDGEMENT

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