Shaking table test of a base isolated model in main control room of Nuclear Power Plant using FPS (Friction Pendulum System)

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1. Introduction

FPS(Friction Pendulum System) is a widely used isolation system which is installed between equipment and foundation to reduce seismic vibration from ground and which is suggested by Zayas, Mokha, Constatinou etc [1]. Natural frequency of the structure is determined regardless of surcharge load by changing radius of curvature of FPS. The properties of FPS are mainly affected by the coefficient of friction and its main factors are velocity of the friction surface, friction surface pressure and surface roughness [2,3].

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 isolation system were conducted to evaluate floor isolation effectiveness of FPS.

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 is 400kg.

Figure 1. Cabinet

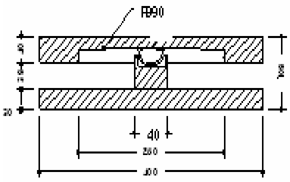
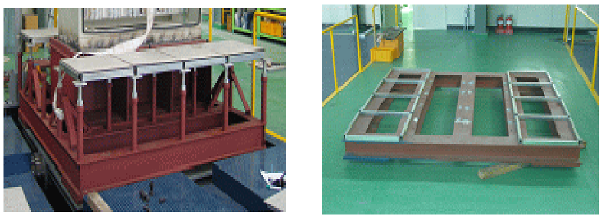


Figure 2. FPS

Four identical FPS were mounted beneath the bare frame model to evaluate the efficiency of the FPS under different ground motions. The Properties of FPS are summarized in Table 1 and Fig 2 shows the schematic view of FPS.

Table 1. Specification of FPS

Natural Frequency	0.5Hz	Bearing dia.	40mm
Compressive design load	2tonf	Bearing surface	12.56cm^2
Radius of curvature	0.99m	Bearing material	Unfilled PTFE



(a) Floor system Type I (b) Floor System Type II

Figure 3. Two different type of Floor System

Fig. 3 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 summarized in Table 2.

Table 2. Floor system dimension

Type	W × D × H (m)	Weight	Material
Type I	2.5 × 2.5 × 0.8	2ton	H-200×200×8×12
Type II	2.5 × 2.5 × 0.2	1ton	H-200×200×8×12

2.2 Input motion

Five different input motions are summarized in table 3.

Note that the peak acceleration responses of three earthquake motions (El-Centro, Hachinohe, Kobe) are distributed in lower frequency range, whereas two design ones (OBE,SSE) are in higher frequency range. Fig 4 shows floor response spectrum of Uljin N.P.P at 144ft.

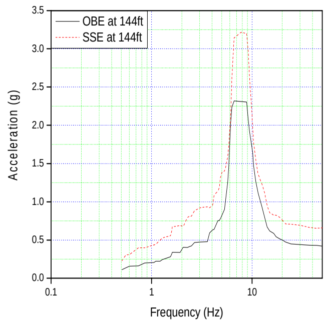


Figure 4. OBE & SSE

Table 3. Input motion profile

Earthquake	Year	M	duration	GPA (g)	Note
El-Centro	1940	6.5	53.74	0.349	
Hachinohe	1968	7.9	36.00	0.229	
Kobe	1995	7.2	50.00	0.209	50% level
OBE(144ft)				0.554	FRS, 5% damp.
SSE(144ft)				0.753	FRS, 5% damp.

2.3 Shaking Table Tests

In order to acquire the response of the cabinet, 3 accelerometers were attached at the lateral surface of the cabinet (top, mid, btm) and several shaking table tests were performed to verify seismic effectiveness of FPS.

3. Test Results and discussion

3.1 Acceleration Comparison

The measured maximum floor accelerations for bare frame and isolated model under 5 strong ground motions are presented in Table 4. With the provision of a FPS, a significant reduction was seen especially in OBE & SSE

Table 4. Maximum floor acceleration

Input Motion (Max. Acceleration, g)		Top		Mid		Btm	
		W/O LRB	With LRB	W/O LRB	With LRB	W/O LRB	With LRB
El-Centro (0.349)	Type I	0.435	0.173	0.362	0.137	0.305	0.097
	Type II	0.485	0.244	0.422	0.190	0.349	0.131
Hachinohe (0.229)	Type I	0.190	0.173	0.205	0.133	0.169	0.093
	Type II	0.192	0.179	0.222	0.152	0.198	0.109
Kobe (0.209)	Type I	0.218	0.141	0.203	0.106	0.126	0.083
	Type II	0.183	0.142	0.228	0.119	0.196	0.090
OBE (0.554)	Type I	2.030	0.280	1.706	0.187	0.531	0.098
	Type II	1.900	0.266	1.622	0.195	0.562	0.122
SSE (0.753)	Type I	2.680	0.284	2.362	0.184	0.731	0.083
	Type II	2.520	0.253	2.300	0.177	0.770	0.112

Fig. 5 shows maximum response reduction ratio of the cabinet. As it was seen in Table 4, there was a great decrease in OBE & SSE of which predominant frequency range is higher than the other input motions.

$$\text{Where Max. reduction ratio} = \frac{\textit{Acquired Cabinet GPA}}{\textit{Input GPA}}$$

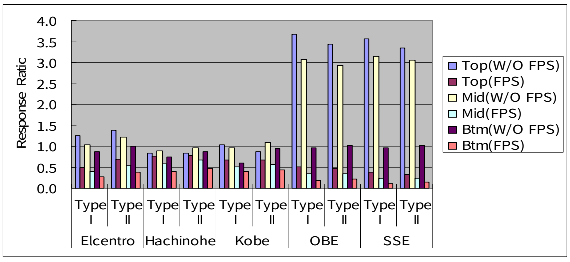
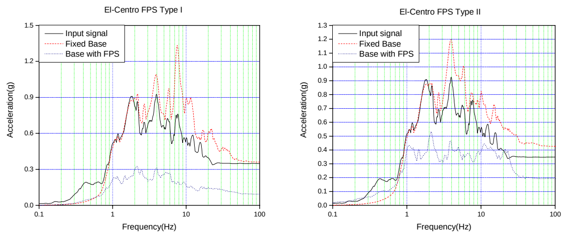


Figure. 5 Max. response reduction ratio

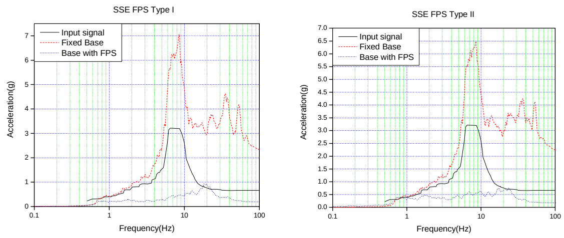
3.2 Response Spectrum

Acceleration response spectra at the middle of the cabinet are presented in Fig. 6 and 7. Large acceleration reduction effect was seen especially in long periodic input motions(OBE, SSE). Peak frequency range is moved to lower one in short periodic input motion, and in long periodic input motion, vice versa. And there was little difference between type I and type II



(a)Type I (b)Type II

Figure 6. Acceleration Response spectrum (El-Centro)



(a)Type I (b)Type II

Figure 7. Acceleration Response spectrum (SSE)

4. Conclusion

To evaluate floor isolation effectiveness of FPS, several shaking table tests with and without isolation system were conducted. Both types have showed large reduction effectiveness in acceleration, response spectra but Type II have showed lower acceleration and lower first mode in response spectra, compared to type I. On the basis of test results and consideration of application, it is found that type II is more suitable for floor model of main control room of Nuclear Power Plant.

ACKNOWLEDGEMENT

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