Shaking table test of a base isolated model in main control room of Nuclear Power Plant using LRB (Lead Rubber Bearing)

K. W. Ham,a K. J. Lee,a Y. P. Suh,a
a Structural Engineering Lab., KEPRI, 103-16, Munji, Yuseong, Daejeon, camael83@kepri.re.kr

1. Introduction

LRB(Lead Rubber Bearing) is a widely used isolation system which is installed between equipment and foundation to reduce seismic vibration from ground. LRB is consist of bearings which are resistant to lateral motion and torsion and has a high vertical stiffness. For that reason, several studies are conducted to apply LRB to the nuclear power plant [1,2].

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 LRB.

2. Shaking Table Test Procedure

2.1 structural and geometric features

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

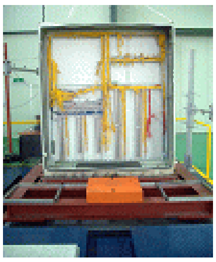


Figure 1. Cabinet

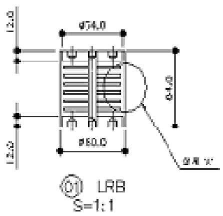
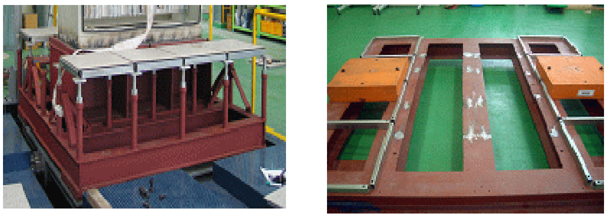


Figure 2. LRB

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

Table 1. Specification of LRB

Natural Frequency	1.5Hz
Compressive design load	700kgf
Shear modulus of rubber	7.5kgf/cm^2
Yield strength	84.5kgf/cm^2



(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	2ton	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.

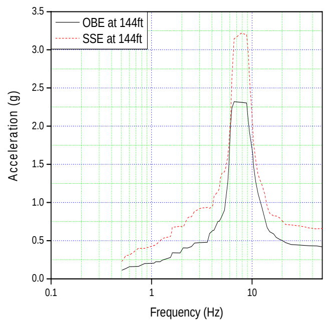


Figure 4. OBE & SSE

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 LRB system.

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 LRB system, a significant reduction was seen under OBE & SSE whereas there were some acceleration amplifications under the other motions.

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	0.633	0.362	0.573	0.305	0.516
	Type II	0.485	0.703	0.422	0.590	0.349	0.570
Hachinohe (0.229)	Type I	0.190	0.338	0.205	0.266	0.169	0.246
	Type II	0.192	0.335	0.222	0.250	0.198	0.235
Kobe (0.209)	Type I	0.218	0.408	0.203	0.395	0.126	0.340
	Type II	0.183	0.427	0.228	0.358	0.196	0.303
OBE (0.554)	Type I	2.030	0.311	1.706	0.262	0.531	0.239
	Type II	1.900	0.292	1.622	0.249	0.562	0.240
SSE (0.753)	Type I	2.680	0.726	2.362	0.607	0.731	0.412
	Type II	2.520	0.618	2.300	0.426	0.770	0.354

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.

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

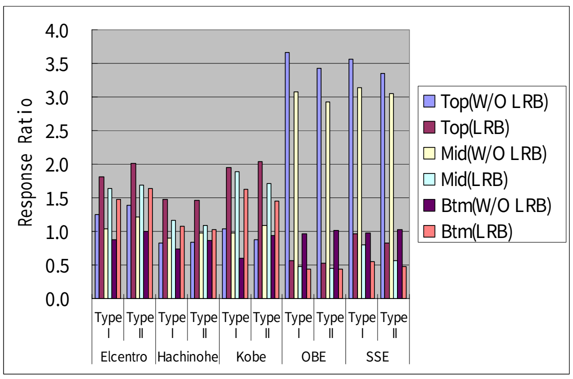
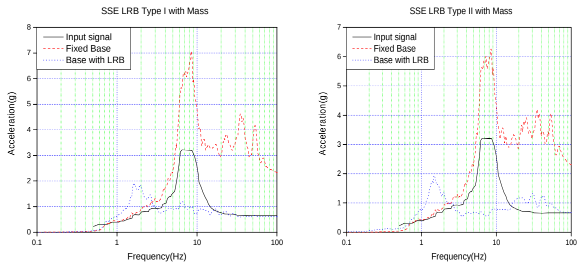


Figure. 5 Max. response reduction ratio

3.2 Response Spectrum

Acceleration response spectra at the middle of the cabinet are presented in Fig. 6. Large acceleration reduction effect was seen in long periodic input motions (OBE, SSE) while there were some amplifications in short ones(El-Centro, Hachinohe, Kobe). And there was little difference between type I and type II



(a)Type I (b)Type II

Figure 6. Acceleration Response spectrum (SSE)

4. Conclusion

To evaluate floor isolation effectiveness of LRB, several shaking table tests with and without isolation system were conducted. As a result of several tests, both types have showed large difference according to input earthquake signals, but showed little difference according to floor type. And it showed large seismic reduction effect when subjected to long periodic earthquake motions. Also it is required to make LRB of which design frequency is below 1Hz when applied to main control room of NPP, but considering much difficulties in making such LRB, it is recommended that consideration should be taken into account when applied to main control room of NPP.

ACKNOWLEDGEMENT

This research was financially supported by Ministry of Commerce, Industry and Energy and Korea Electric Power Research Institute and the authors are grateful to the authorities for their support.

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