

# **Comparative Study of Multi-Storey Building with Different Base Isolators**

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**ABSTRACT:** Base isolation is an effective means for protection of structure during earthquake events. The concept of Base isolation is to insert a flexible layer between foundation and superstructure thus decoupling the building from damaging action of ground motion. This results in reduced frequency range and dissipates energy through damping. The paper presents comparative study of performance of three types of base isolators namely High Damping Rubber bearing (HDRB), Low Damping Rubber Bearing (LDRB) and Lead Rubber Bearing (LDRB). A 8-storey building has been analysed using Response Spectrum Method. Dynamic analysis has been done using STAAD Pro software. Parameters like Base shear, Building displacement and frequency and spectral acceleration are compared for the building with base isolator and building with fixed base.

**KEYWORDS:** Base isolation, damping, energy dissipation, response spectrum, stiffness.

## **I. INTRODUCTION**

The base isolation technique is a seismic design approach in which, due to the insertion of a flexible layer between the foundation and the superstructure, the fundamental frequency of the system decreases to a value lower than the predominant energy containing frequencies of earthquake ground motion. In addition, the damping capacities provided by the isolation systems help dissipate the energy imparted during seismic activities.

Seismic base isolation, which is now recognized as a mature and efficient technology, can be adopted to improve the seismic performance of strategically important building such as schools, hospitals, industrial structures, multi-storey buildings etc. In order to minimize inter storey drifts, in addition to reducing floor accelerations; the concept of base isolation is increasingly being adopted. Base isolation (BI) has also been referred to as passive control.

### **High Damping Rubber Bearing:**

HDRB is one type of elastomeric bearing. This type of bearing consist of thin layers of high damping rubber and steel plates built in alternate layers as shown in Figure. Horizontal stiffness of the bearing is controlled by the low shear modulus of elastomer while steel plates provides high vertical stiffness as well as prevent bulging of rubber. High damping rubber bearing provides damping in the range of 10% to 20%.

### **Low damping rubber bearing:**

Rubber bearings have two steel endplates and many thin steel shims interblended with the rubber. The steel shims can provide the capability of the vertical stiffness but have no effect on the horizontal stiffness, which is dominated by the shear modulus of elastomer. The material in shear is quite linear up to shear strains above 100% with damping in the range of 2-3%.

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## Lead rubber bearing:

A lead-rubber bearing is formed of a lead plug force-fitted into a pre-formed hole in an elastomeric bearing. The lead core provides rigidity under service loads and energy dissipation under high lateral loads. When subjected to low lateral loads such as minor earthquake the lead-rubber bearing is stiff both laterally and vertically. The lateral stiffness results from the high elastic stiffness of the lead plug and the vertical rigidity. A major advantage of the lead-rubber bearing is that it combines the functions of rigidity at service load levels, flexibility at earthquake load levels and damping into a single compact unit.

## II. MODELLING OF A STRUCTURE

Fig. 2 shows the idealized mathematical model of the 8 – storey base isolated building considered for the present study.

## III. DESCRIPTION OF BUILDING

A eight-storey reinforced concrete office building is located on a medium soil

Storey height	: 3m
Size of beams	: 0.3m x 0.5m
Size of columns	: 0.5m x 0.5m
Thickness of wall	: 0.15m
Thickness of slab	: 0.15m
Dead load	: 8 KN/m
Live load	: 2.5 KN/m <sup>2</sup>
Density of concrete	: 25 KN/m <sup>3</sup>
Modulus of elasticity	: 25000 N/mm <sup>2</sup>
f <sub>ck</sub>	: 25 N/mm <sup>2</sup>
f <sub>y</sub>	: 415 N/mm <sup>2</sup>
Span width in X – direction	: 6m (2–bay)
Span width in Z – direction	: 4m (2–bay)

By a static analysis using the software (STADD Pro program) the loads are computed for all the columns at their base, where the bearings are to be installed. The maximum load on column is 2986 KN. The weight of structure is 3340 KN. The maximum relative displacement is 35mm.

## IV. BEARING DETAILS OF BUILDING

TABLE I - DETAILS OF BEARING

Sr.No.	Dimensions of Bearing	HDRB	LDRB	LRB
1	Diameter of Bearing	410mm	516mm	590mm
2	Thickness of individual rubber layer	10mm	12mm	12mm
3	Numbers of rubber layer	25	34	21
4	Thickness of individual steel plates	2mm	2mm	2mm
5	Numbers of steel plates	24	33	20
6	Thickness of top and bottom steel plates	25mm	25mm	25mm
7	Total height of bearing	348mm	524mm	342mm
8	Diameter of lead core	-	-	275mm

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Table I shows dimensions of bearing which are calculated on the basis of required stiffness. Time period is assumed to be 2 sec.

Stiffness of HDRB: 544 KN/m

Stiffness of LDRB: 486 KN/m

Stiffness of LRB: 745KN/m

## V. COMPARATIVE STUDY WITH DIFFERENT BASE ISOLATORS AND WITH FIXED BASE

TABLE II  
FREQUENCY OF BUILDING WITH AND WITHOUT ISOLATOR

Mode	Frequency(cycles/sec)			
	With Fixed base	With HDRB	With LDRB	With LRB
1	1.0730	0.552	0.527	0.662
2	1.229	1.073	1.073	1.073
3	1.299	1.222	1.221	1.225
4	3.288	2.571	2.556	2.620
5	3.475	3.288	3.288	3.288
6	3.831	3.475	3.475	3.475

Table II shows values of frequencies for their respective modes that are obtained by dynamic analysis of structure by response spectrum method for building with fixed base and building isolated with different isolators. Study shows that frequency has different values in initial modes. But values are nearly same in mode 5 and mode 6.

TABLE III  
SPECTRAL ACCELERATION OF BUILDING WITH AND WITHOUT ISOLATOR

Mode	Spectral Acceleration			
	With Fixed base	With HDRB	With LDRB	With LRB
1	1.459	0.751	0.716	0.852
2	1.671	1.459	1.459	1.459
3	1.766	1.662	1.66	1.666
4	2.5	2.5	2.5	2.5
5	2.5	2.5	2.5	2.5
6	2.5	2.5	2.5	2.5

Table III shows spectral acceleration values in different modes. Values differ in mode 1,2and 3 but it is constant in mode 4, 5 and 6.

TABLE IV  
PEAK STOREY SHEAR OF BUILDING WITH AND WITHOUT ISOLATOR

Floor	Peak Storey Shear (KN)			
	With Fixed base	With HDRB	With LDRB	With LRB
9	53.59	18.94	17.88	22.19
8	101.87	37.43	35.37	43.73
7	143.16	55.29	52.30	64.33
6	177.59	72.39	68.58	83.33
5	206.67	88.72	84.2	102.22

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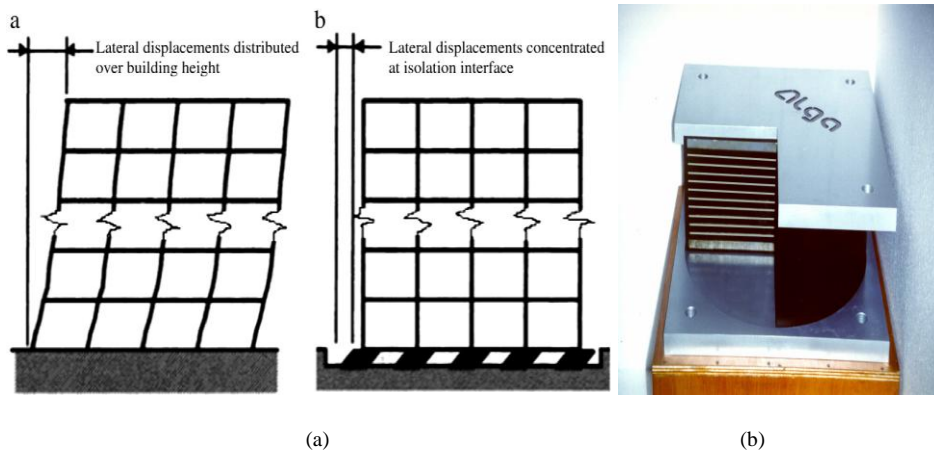
4	231.51	104.38	99.22	119.63
3	251.55	119.45	113.73	136.20
2	264.77	134.0	127.79	152.03
1	269.86	148.08	141.44	167.17
0	269.86	148.08	141.44	167.17

Table IV shows values of base shear at different storeys. In response spectrum method base shear is the most important parameter to be extracted. Base shear is maximum at the base and decreases as the height increases. Lead rubber bearing gives minimum value of base shear.

TABLE V  
AVG. DISPLACEMENT OF BUILDING WITH AND WITHOUT ISOLATOR

Floor	Avg. Displacement(cm)			
	With Fixed base	With HDRB	With LDRB	With LRB
0	0	10.31	11.54	7.535
1	0.3422	10.66	11.89	7.8785
2	0.9593	11.28	12.51	8.4975
3	1.6361	11.95	13.19	9.1745
4	2.3083	12.63	13.86	9.847
5	2.9445	13.267	14.49	10.4829
6	3.5179	13.84	15.07	11.056
7	4.0	14.32	15.55	11.539
8	4.3639	14.68	15.92	11.9024
9	4.5958	14.918	16.15	12.1343

Table V shows displacement values at different storey levels. Displacement increases linearly with storey height. Lead rubber bearing shows maximum displacement at top storey.



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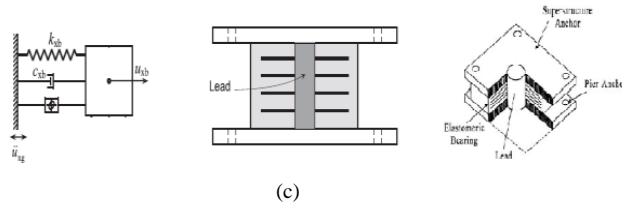


Fig. 1(a) Comparison of Base Isolated and Fixed Base Building (b) Typical High Damping Rubber Bearing  
(c) Lead Rubber bearing

Fig. 1(a) shows comparison of base isolated and fixed base building. It is clear that due to insertion of flexible layer between foundation and superstructure, lateral displacement is concentrated at isolation surface in case of isolated building; whereas lateral displacement is distributed over building height in case of fixed base building.

Fig. 1(b) shows typical high damping rubber bearing. It consists of alternate layers of high damping rubber and steel plates. Horizontal stiffness is controlled by rubber and steel plates provide high vertical stiffness.

Fig. 1(c) shows lead rubber bearing. Due to inclusion of central lead plug in laminated rubber bearing, a problem of large displacement of bearing can be alleviated.

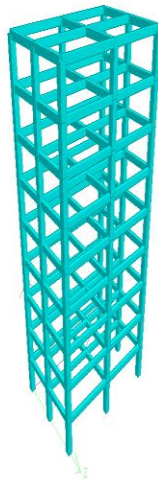
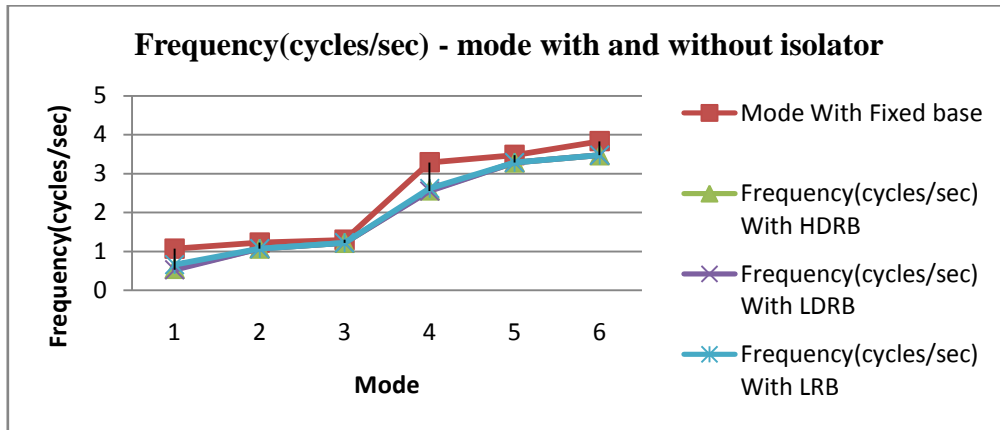
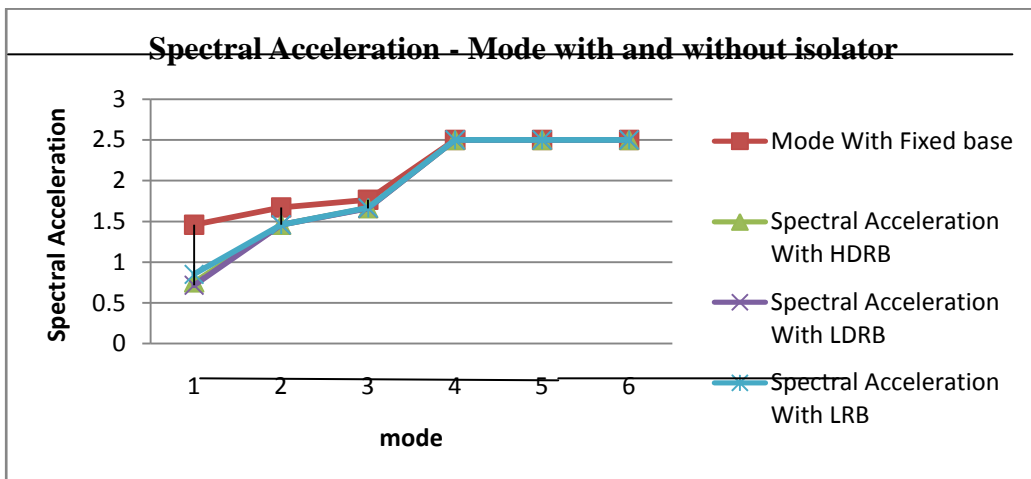


Fig. 2 Mathematical model of 8-storey Building

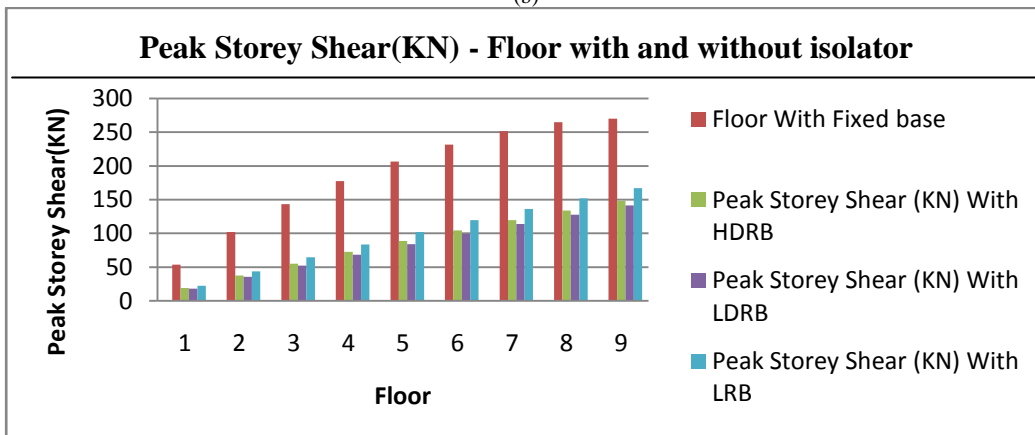
Fig. 2 shows mathematical model of 8-storey building prepared in STAAD Pro software. The building is an ordinary moment resisting frame, located in zone V with response reduction factor as 3. The building is resting on a medium soil.



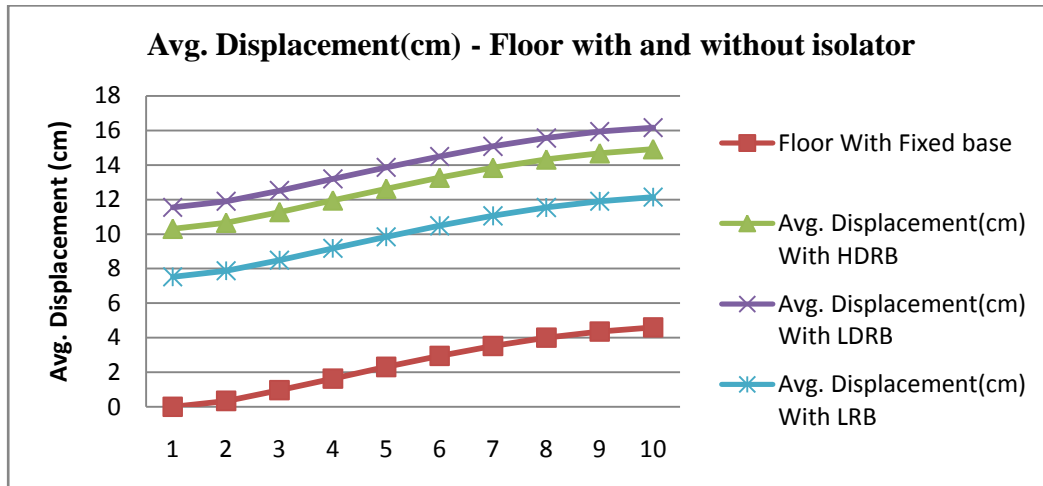
(a)



(b)



(c)



(d)

Fig. 3(a) Frequency(Cycles/sec)-mode shape graph of building with and without isolator (b) Spectral acceleration-mode shape graph of building with and without isolator (c) Peak storey shear – floor No. Graph of building with and without isolator (d) Avg. Displacement – floor no. Graph of building with and without isolator.

Fig. 3(a) shows Frequency (cycles/sec)-mode shape graph. It is seen that frequency has reduced due to insertion of base isolators in a building.

Fig. 3(b) shows spectral acceleration –mode graph. It is clear from the graph that spectral acceleration is lowest when building is isolated with low damping rubber bearing.

Fig. 3(c) shows Peak storey shear vs. Floor no. graph. Graph shows comparative value of peak storey shear of fixed base and base isolated building. It can be seen that peak storey shear has minimum value when isolated with low damping rubber bearing.

Fig. 3(d) shows Avg. Displacement vs. Floor no. graph. Displacement has increased in case of base isolated building as compared to fixed base structure. Also displacement has highest value when isolated by low damping rubber bearing.

## VI. CONCLUSION

Seismic base isolation method has proved to be a reliable method of earthquake resistant design. Different types of isolators have been proposed and detailed research has been made on them. Dynamic Response Spectrum Analysis is carried out for 8-storey office building. The structure is analysed with fixed base and by providing different base isolator. Comparative study of different parameters like frequency, spectral acceleration, base shear, and displacement is carried out without provision of isolator and with provision of different base isolators. Results of analysis can be summarised as follow:

1. The performance of base isolated building is better compared to the fixed base building.
2. In mode 1, Low damping rubber bearing gives lowest frequency.
3. There is 47% reduction in base shear when isolated with LDRB as compared to the fixed base building. The reduction in base shear are 45% and 38% respectively when isolated with HDRB and Lead rubber bearing as compared to the fixed base.

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4. Displacement has increased in all three isolators. The displacements in Low damping rubber bearing, HDRB and Lead rubber bearing are 16.15cm, 14.918cm and 12.13cm respectively.

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