Seismic Response of Asymmetric Reinforced Concrete Structure with Lead Rubber Bearing

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Abstract **- In this research paper consists "seismic analysis of asymmetric reinforced concrete structure with lead rubber bearing". The configuration of buildings is G+4 and G+9 with storey height is 3m taken. In this work ,the proposed building frame structure with various input parameter such as 5 and 10 multi-storey frame, size of columns are 350X350mm and 400X400mm respectively, size of beams are 300X350mm in both the cases, thickness of slab is 150mm. Live load is 4 KN/m^2,Grade of reinforcement used Fe415, Both the cases are considered to be located in seismic zone III IS 1893 (Part-I):2002. Seismic zone factor, Z=0.3(UBC 97, Vol-2, Table 16-I & Zone Map), Seismic coefficient, C_V = C_{VD}=0.54(UBC 97, Vol-2, Table 16-R), Response Reduction Factor, R for SMRF=8.5(UBC 97, Vol-2, Table 16-N), Damping coefficient, B_d or B_m=1 Interpolate (UBC 97, Vol-2, Table A-16-C) ,etc are taken.average drift for 5 storey structure reduces to almost 53% while in case of 10 storey structure it reduces to 26% only w.r.t. fixed base structure. average percentage reduction in storey shear of LRB building w.r.t. fixed base building is 48.765% and 70.37% in 5 and 10 storeys building, respectively.**

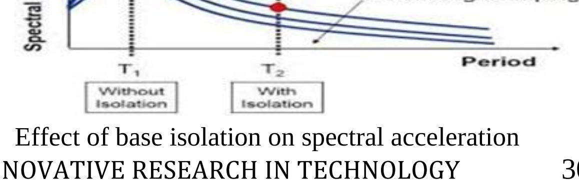
Index Terms **- Seismic Zones, Base Isolation, Lead Rubber Bearing, Dynamic Analysis, Etabs Software.**

I.INTRODUCTION

The ground movement which occurred naturally that creates disaster and cause damage to structures is called Earthquake. In the earth's crust seismic activities occur that creates waves. These waves transmit to structures through foundation. Thus, due to this earthquake movements, inertia force is invoked in structure resulting in damaging the whole or part of structure. On the other hand, earthquakes provide architects and engineers with a number of important design criteria which are unknown to the normal design process. Engineers are allowed to use ductility for attainment of more deformation on the structure than the usually permitted elastic limit. Elastic limit means the maximum point at which the structure can be deformed and then regain its original shape. Cracks will develop in the structure if the building deforms more than its elastic limit.

Base Isolation

In seismic zones and high-risk areas for constructing bridges, flyovers and buildings Base isolation is being commonly used in the past few years. There are many projects made and many are under construction in which base isolation is applied. At the time of earthquake, the movement of the ground occurs laterally and disrupt the structure. So, there is a need to bifurcate the structure from the ground by inserting flexible isolation system between the structure and the foundation and therefore the aftereffects and shocks of the earthquake will be minimized by doing this. Thus, the stability of the structure remains for longer period because of low seismic energy is transmitted in the structure. The prime factors which are being used in maintaining the flexibility of structure are Rubber bearing and Lead Rubber. These helps in increasing the usual period of the structure as a whole and base displacement is greater than the prearranged limit. The time period shift is shown in the Fig.

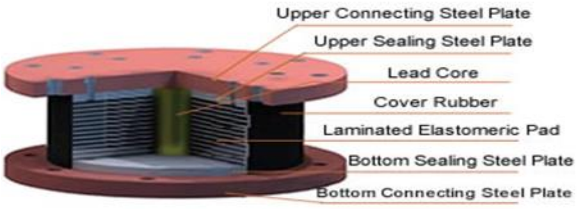


Effect of base isolation on spectral acceleration

Lead Rubber Bearing (LRB)

New Zealand was the first country to use Lead Rubber Bearing in year 1975 afterwards it was used in New Zealand, Japan and United States at a large scale. To support the structure and provide ground flexibility to the structure one or more lead plugs are installed in the bearing.

With the lead core with diameter ranging from 15% to 33% of bonded diameter and low damping elastomers the LRB is constructed as shown in fig.



Lead Rubber Bearing (LRB)

II-LITERATURE REVIEW

Avinash A.R, Rahul N.K, Kiran Kamath studied the the impact of height changing of a base isolated structure on torsional response has been explore. For the analysis of structure are base isolated by lead rubber bearing (LRB). The elevation of the structure is changed trumphant and subjected to two direction seismic excitation. The maximum diminishion in torsional movement by LRB isolator is 92.315% for twelve story building for Chi-Chi earthquake. It is 91.625% for twelve story building in Kobe and 73.091% for eleven story building in El-Centro seismic.

Sonali Anilduke1, Amay Khedikar2. Studied that All over chronical time seismic are one of the natural threats that obtain due to instant vicious vibration of earth's surface which causes destroyed to field, mainly to man-made building. Base isolation is one of the most equipment of seismic engineering pertaining to the passive structural movement restrict technologies. This paper recent three-dimensional nonlinear time history analysis is presentation on r/c structure the use of computer program SAP 2000 v12.0.0. The dynamic study of the building has been used and the presentation of the structure with and without isolator is analysis.

Shirol and Kori (2017), contemplate a G6 storey dummy with and without masonary infill. Lead rubber bearing and abrasion type isolators were used. The infill was modelled as single bevelled swagger. The static and response spectrum analysis are implement using ETABS-2016. From the analysis it was culminate that equipping of isolators escalate the natural time period which abolish the prospect of sonority. The base shear and the storey drifts got diminished noteworthy while the deracination escalates which is due to the pliability transmitted to the buildings. The deliberation of infill operation escalates the base shear while the deracination and inter storey drifts showed diminished bias. The base shear diminished by 50% for bare fixture dummy and 70% for models with masonry infill in static method. The base shear diminished by 46 % and 42% in bare fixture and by 71% and 65% for infill buildings for rubber isolator and abrasion isolator discretely by response spectrum method. The escalate in deracination at foundation is 19.38 mm and 14.48mm for LRB and FPS isolator for response.

Jain and Thakkar (2004) studied the analytical behaviour of base-isolation for buildings with higher natural period ranging from 1.0 to 3.0 second. Different possibilities were explored to increase the feasibility of base isolation for such type of buildings. Plans suggest in this analysis were (i) expand superstructure stiffness, (ii) expand superstructure damping and (iii) expand flexibility of isolation system. It was observed that the effectiveness of base isolation for these buildings may be increased by incorporating such provisions. Three buildings having 10, 14 and 20 storeys were analysed in this study. Base isolation results in noteworthy depletion in structural reaction of stiffened buildings as differentiate to unstiffened one. There is no noteworthy dissimilarity between the rection of the base isolated buildings with and without superstructure stiffening though the impact of superstructure stiffening is more in case of huge buildings. Stiffening of superstructure of base-isolated buildings results in reduction of the maximum roof acceleration and the maximum storey drift while it increases the maximum storey shear and the maximum base slab displacement. extension in the damping of superstructure decrease the seismic reaction of base-isolated buildings though the depletion is not substantial. Superstructure damping has less sequel on largest base deracination of base-isolated buildings.

III-METHODOLOGY& MODELLING APPROACH

Methodology

In this attempt, following major cases will be analysed:

1. An extensive survey of the literature on the response of base isolation to seismic loading is performed.
2. Provisions related to seismic analysis of base isolation are presented.
3. Modelling of different height of structures, which is five and ten.
4. To carry out the study on dynamic analysis for different models of specified cases.
5. To plot the graphs between Storey Displacement vs. Storey height, storey Drift vs. Storey height, Base shear compare results for variations.

Modelling Approach

The modelling approach includes the development of model, using ETABs 2016; dynamic analysis has been carried out.

3.3 Analysis Procedure

3.3.1 Equivalent Static Analysis

The effect of earthquake ground motion is defined in equivalent static analysis methods by series of forces acting on a structure. On the basis of mass and stiffness the computed base shear is distrusted along the floors of building. Depending upon the floor diaphragm action the obtained lateral force at each floor are being disturbed to lateral load resisting elements.

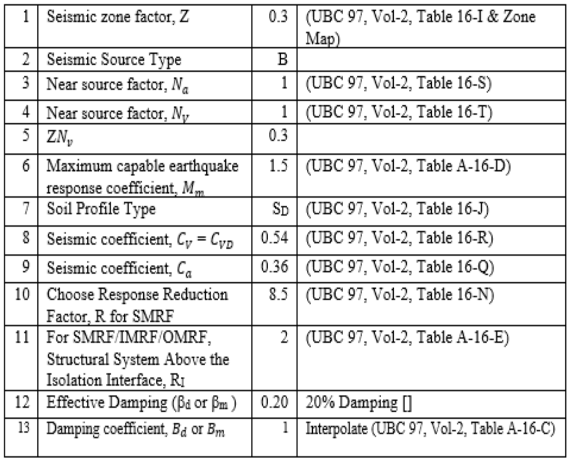
3.3.2 Response-spectrum analysis (RSA)

In any elastic structure to indicate maximum seismic response for the contribution of each natural mode of vibration linear dynamic statistical analysis method is adopt. For any given time, history and level by measuring pseudo-spectral acceleration, velocity or displacement, intuition of dynamic behaviour can be done by response spectrum analysis. For the selection of structural design on the basis of its response to dynamic performance response spectrum analysis is quite useful. Structures with higher time period experience more displacement while the one with shorter time period experience more acceleration.

3.1 LRB Design

3.1.1 Lateral Load for Response Spectrum Analysis (according to UBC 1997)

Table 3.3.1 Input Data for LRB design



1	Seismic zone factor, Z	0.3	(UBC 97, Vol-2, Table 16-I & Zone Map)
2	Seismic Source Type	B	
3	Near source factor, N_a	1	(UBC 97, Vol-2, Table 16-S)
4	Near source factor, N_v	1	(UBC 97, Vol-2, Table 16-T)
5	ZN_v	0.3	
6	Maximum capable earthquake response coefficient, M_m	1.5	(UBC 97, Vol-2, Table A-16-D)
7	Soil Profile Type	S_D	(UBC 97, Vol-2, Table 16-J)
8	Seismic coefficient, $C_V = C_{VD}$	0.54	(UBC 97, Vol-2, Table 16-R)
9	Seismic coefficient, C_a	0.36	(UBC 97, Vol-2, Table 16-Q)
10	Choose Response Reduction Factor, R for SMRF	8.5	(UBC 97, Vol-2, Table 16-N)
11	For SMRF/IMRF/OMRF, Structural System Above the Isolation Interface, R_I	2	(UBC 97, Vol-2, Table A-16-E)
12	Effective Damping (β_d or β_m)	0.20	20% Damping []
13	Damping coefficient, B_d or B_m	1	Interpolate (UBC 97, Vol-2, Table A-16-C)

DESIGN OF BASE ISOLATOR

1 Maximum Vertical Load Column Support, W is Taken as vertical load of Column.

1 Time Period = 2.5 [10]

2 Shear Modulus G = 0.7

3 Design Displacement D_D $D_D = (\frac{g}{4\pi^2})\frac{C_{VD}T_D}{B_D}$

4 Bearing Effective Stiffness, K_{eff}

$$K_{eff} = \frac{w}{g} * (\frac{2\pi}{T_D})^2$$

5 Force at design displacement or characteristic strength (Q) $Q = \frac{W_D}{4D_D}$

6 Energy dissipiated per cycle, W_D $W_D = 2\pi K_{eff} {D_D}^2 \beta_{eff}$

7 Stiffness of Rubber K_2

$$K_2 = K_{eff} - \frac{Q}{D_D}$$

Where, $\frac{Q}{D_D}$ = Stiffness of lead Core

8 Yield Displacement D_y (Distance from J End) $D_y = \frac{Q}{K_1 - K_2}$

We Know that $K_1 = 10K_2$

9 Recalculation of Q to Q_R $Q_R = \frac{W_D}{4*(D_D - D_Y)}$

10 Calculation of Area and Diameter Of lead plug

Yield Strength of Lead Varies Between 10 – 18 Mpa

So, we will Take it as F_{pb} = 10Mpa

Area of Lead Plug

$$A_{pb} = \frac{Q_R}{F_{pb} * 10^3}$$

Diameter of Lead Plug

$$D_{pb} = \sqrt{A_{pb}\frac{4}{\pi}}$$

11 Recalculation of Rubber stiffness K_{eff} to $K_{eff(R)}$

$$K_{eff(R)} = K_{eff} - \frac{Q_R}{D_D}$$

12 Total Thickness of rubber Layer, t_r $t_r = \frac{D_D}{\Upsilon}$

Where, ϒ = 100% (maximum shear strain of rubber)

13 Calculation of Area and Diameter of Bearing

Area of Bearing

$$A_{LRB} = \frac{K_{eff(R)} * t_r}{G}$$

Diameter of Bearing

$$D_{LRB} = \sqrt{A_{LRB} * \frac{4}{\pi}}$$

14 So, Shape Factor, S $S = \frac{1}{2.4} * \frac{f_v}{f_h}$

Where,

f_v = Vertical Frequency f_h = Horizontal Frequency

$f_h = \frac{1}{2}$ = 0.5 Hz

Consider, f_v = 10 Hz

Also,

$$S = \frac{D_{LRB}}{4t}$$

Where, t = Single layer Thickness ∴ $t = \frac{D_{LRB}}{4S}$

So, number of Rubber Layers, N $N = \frac{t_r}{t}$

15 Dimensions of LRB

Let us Assume thickness of shim plates be, t_s3.1mm

Number of shim plates = N-1

End Plate Thickness is between 19mm to 38 mm, Assume, 30mm.

So Total Height of LRB, h

h = (N*t_r) + ((N-1) *t_s) + 30 mm

Let us Assume Cover be, 30 mm.

So, Bonded Diameter

$B = D_{LRB} - 2(30)$ mm

16 Compression Modulus, E_c $E_c = 6GS^2(1 - \frac{6GS^2}{K})$

17 Where, K = Bulk Modulus (2000 Mpa)

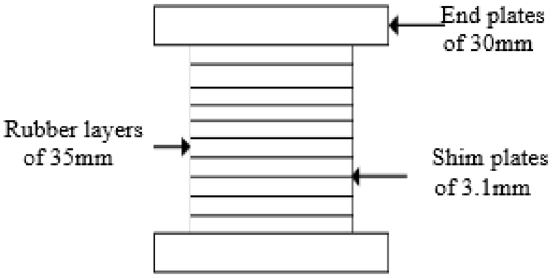
18 Horizontal Stiffness K_H $K_H = \frac{GA_{LRB}}{t_r}$

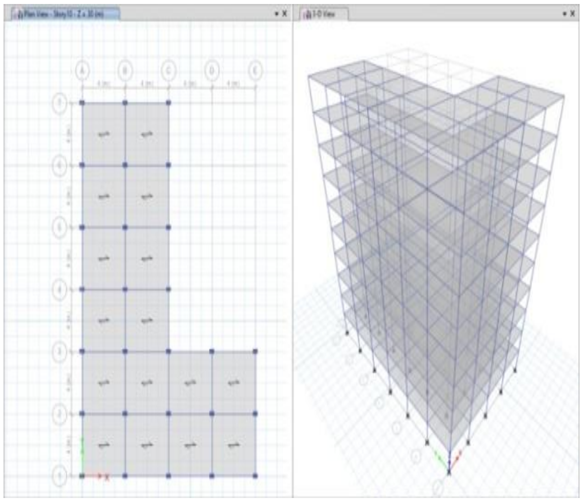
19 Vertical Stiffness, K_V $K_V = \frac{E_C A_{LRB}}{t_r}$

20 Moment of Inertia, I Since Circular LBR $I = \frac{\pi}{64}B^4$

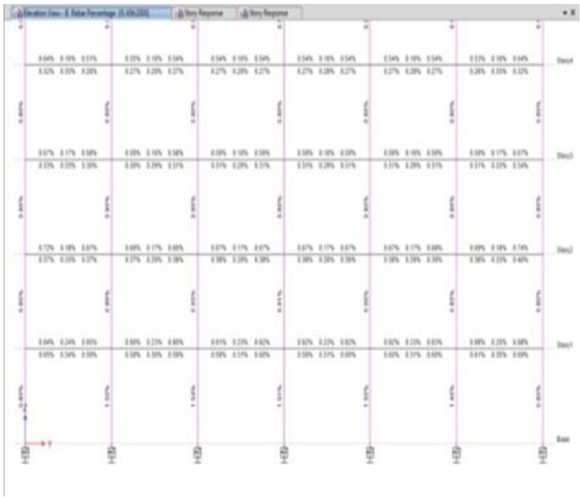
21 Yield Strength, F_y

$$F_y = Q + K_2 * D_y$$





Bare frame model



Percentage of Steel in Isolated Structure

Details of 5-storey building

Members	Size of Member (in mm)
Column (M 25)	350X350
Beam (M25)	300X350

Rotational Inertia	0.00135745	KN/m
For U1 Eff. Stiff.	1056379.701	KN/m
For U2 & U3 Eff. Stiff.	1056.377	KN-m
For U2 & U3 Eff. Damping	0.20	
For U2 & U3 Distance from End-J	0.00490	M
For U2 & U3 Stiffness	8074.760786	KN/m
For U2 & U3 Yield Strength	39.58906743	KN

Details of 10-storey building

The configuration of building is G+9. Storey height provided is 3m. Thickness of slab is 150mm. Live load is 4KN/m2.Grade of reinforcement used was Fe415.

Members	Size of Member (in mm)
Column (M 25)	400X400
Beam (M25)	300X350

Rotational Inertia	0.00566423	KN/m
For U1 Eff. Stiff.	2012151.733	KN/m
For U2 & U3 Eff. Stiff.	2012.153	KN-m
For U2 & U3 Eff. Damping	0.20	
For U2 & U3 Distance from End-J	0.00490	M
For U2 & U3 Stiffness	15380.4963	KN/m
For U2 & U3 Yield Strength	75.39822367	KN

IV. RESULTS AND DISCUSSION

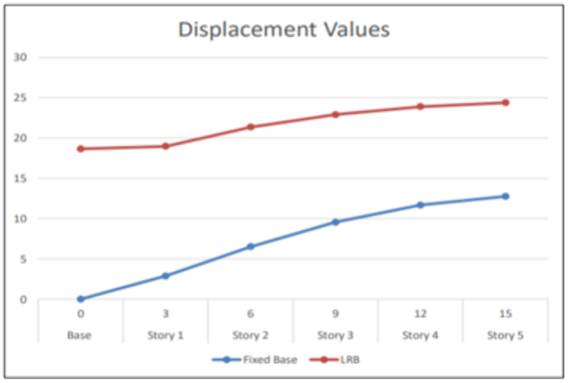
The results were inferred according to the values obtained by the dynamic analysis carried out on 5 and 10 storey. The graphs of the parameters are shown in this chapter along with the discussion.

Following are the cases on which study has been carried out:

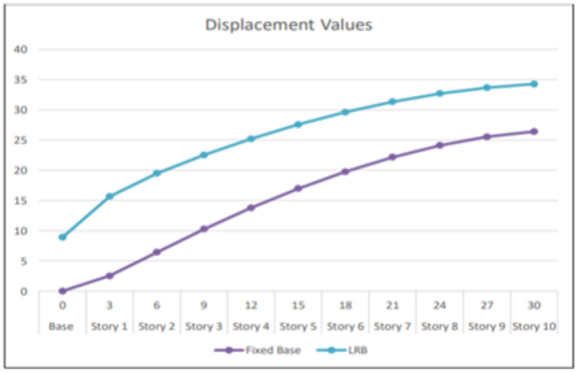
Case 1: Frame with Fixed Base

Case 2: Frame with LRB Base.

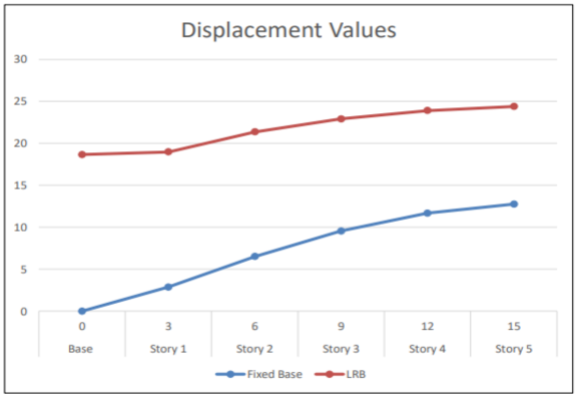
Plots: Displacement v/s Storey Height



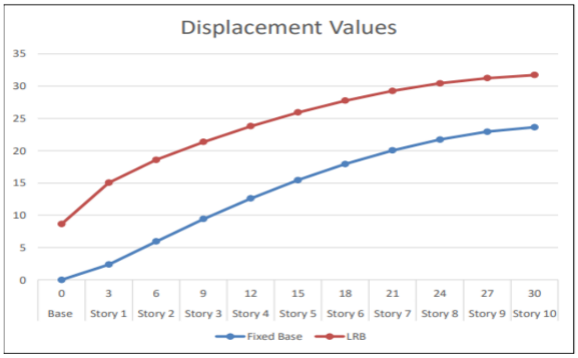
5 Storey X Direction



10 Storey X Direction

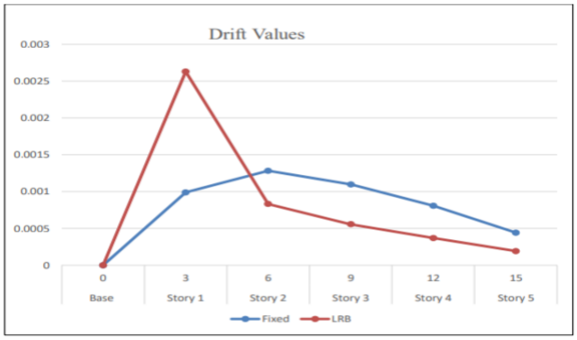


5 Storey Y Direction

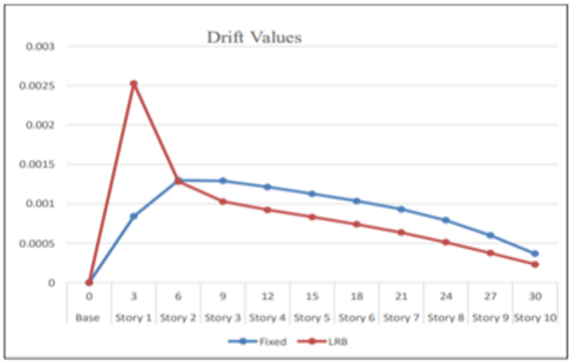


10 Storey Y Direction

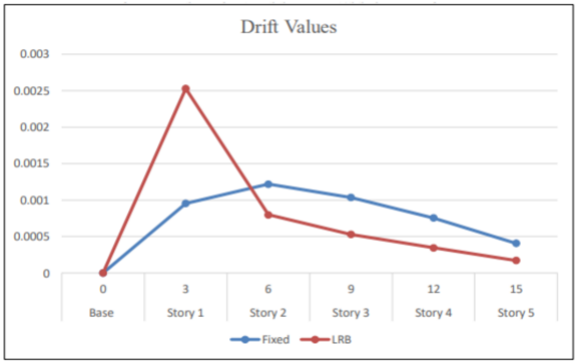
Plots: Drift v/s Storey Height



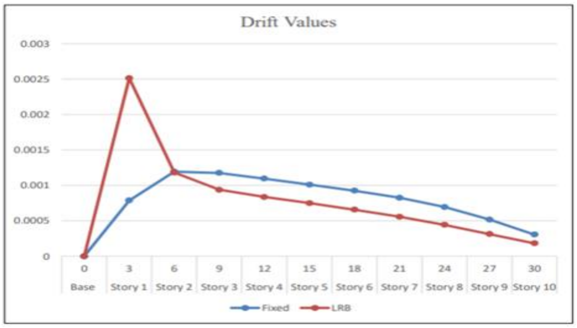
5 Storey X Direction



10 Storey X Direction



5 Storey Y Direction



10 Storey Y Direction

V. DISCUSSION

Within the scope of present work, following conclusions are drawn form results:

1. The average maximum displacement for dynamic analysis of 5 storey building in X-direction, the cumulative displacement of LRB is 44.6% of Fixed base building. Whereas in 10 storey structure up to 5 storey the displacement of fixed base building is approximately similar to cumulative displacement of LRB base and at the top cumulative displacement of LRB is 97.8% of Fixed base building.
2. The above points conclude that use of LRB isolation system in low storey structure is more suitable than high rise structure.
3. The maximum drift reduction with LRB system in 5 storey structure for top stories (60% of stories) are 50.84%, 44.93% and 43.81% in dynamic analysis w.r.t. fixed base building.
4. The maximum drift reduction with LRB system in 10 storey structure for top stories (40% of stories) are 67.97%, 64.78%,63.56% and 62.92% in dynamic analysis w.r.t. fixed base building.
5. The above points (3 and 4) shows in dynamic analysis on top stories with the use of LRB isolation system average drift for 5 storey structure reduces to almost 53% while in case of 10 storey structure it reduces to 26% only w.r.t. fixed base structure.
6. Average percentage reduction in storey shear of LRB building w.r.t. fixed base building is 48.765% and 70.37% in 5 and 10 storey building, respectively.

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