ANALYSIS OF VIBRATION DUE TO SEISMIC WAVE ON (G+9) STORY RESIDENTIAL BUILDING WITH AND WITHOUT LEAD RUBBER BEARING BY RESPONSE SPECTRUM METHOD FOR ZONE 3

DILIP BANJARE[1], DINESH SEN[2]

[1]RESEARCH ASSISTANT, DEPARTMENT OF CIVIL ENGINERING, VEC LAKHANPUR, (A CONSTITUENT COLLEGE OF CSVTU BHILAI, DURG C.G. INDIA)
[2]PROFESSOR, DEPARTMENT OF CIVIL ENGINERING, VEC LAKHANPUR, (A CONSTITUENT COLLEGE OF CSVTU BHILAI, DURG C.G. INDIA)

---***---

ABSTRACT- Non-structural components are sensitive to large ground motion which produces floor accelerations, velocities, and displacements. During an earthquake, the building produces this motion, resulting in peak floor accelerations higher than the peak ground acceleration. Thus earthquake ground motion can cause significant or severe structural damages. The use of energy dissipators is the best method to reduce interstorey drift and floor accelerations. A new type of energy dissipators system is developed here for a multi-storey reinforced concrete building. This work deals with modeling and analysis of (G+9) storey rigid jointed plane frame for two cases. First case is fixed base and second case is isolated. Modeling and analysis is done using ETABS software for design spectrum records. Maximum vertical reaction is obtained from analysis in ETABS software. Using this vertical reaction and total mass of structure lead rubber bearings are designed manually. Response spectrum analysis is carried out in order to evaluate floor response, accelerations and displacements during a ground motion. This paper intends to demonstrate how a dissipation system can be efficient, evaluating its effectiveness for the building in terms of storey shear, storey drift and storey displacement reductions.

KEY WORDS- Eenergy dissipators, *lead rubber bearing,* response spectrum analysis, storey shear, storey drift, storey displacements, ETABS software.

1. INTRODUCTI0N-

All bodies having mass and elasticity are capable to vibrate. The mass is inherent in the body and elasticity causes relative motion among its parts. When body particles are displaced by the application of external force, the internal forces in the form of elastic energy present in the body, try to bring it to its original position. At equilibrium position, the whole of the elastic energy converted into kinetic energy and the body continuous to move in the opposite direction because of it. The whole of the kinetic energy is again converted into elastic or strain energy due to which the body returns to the equilibrium position. In this way, vibratory motion is repeated continuously and interchange of energy takes place. Thus, any motion which repeats itself after an interval of time is called vibration or **oscillation.**

Conventional seismic design attempts to make buildings that do not collapse under strong earthquake shaking, but may sustain damage to non-structural elements and the structural elements like beam, columns and sometime whole buildings. Non-structural components may consist of furniture, equipment, partitions, curtain wall systems, piping, electrical equipment and many other items. This may render the building non-functional after the earthquake, which may be problematic in some structures, like hospitals, residential buildings, and highly importance buildings such as museums, etc, which need to remain functional during the earthquake. Non-structural components are sensitive to large floor accelerations, velocities, and displacements. When a building is subjected to an earthquake ground motion, the building induces motion, resulting in floor accelerations higher than the ground acceleration. Hence, it is present need to earthquake resisting design approach to reduce such type of structural damages. Special techniques are required to design buildings such that they remain practically undamaged even in a severe earthquake. The basic technologies used to protect buildings from damaging earthquake effects. These are energy dissipation devices and seismic dampers.

1.1) Energy dissipation devices:

1.1.1) LEAD RUBBER BEARING: - Lead rubber bearing, applied to building and bridge construction, is a practical and cost effective choice for seismic isolation. It is composed of laminated elastomeric bearing pad, top and bottom sealing & connecting plate and lead plug inserted in the middle of the bearing as shown in following picture.

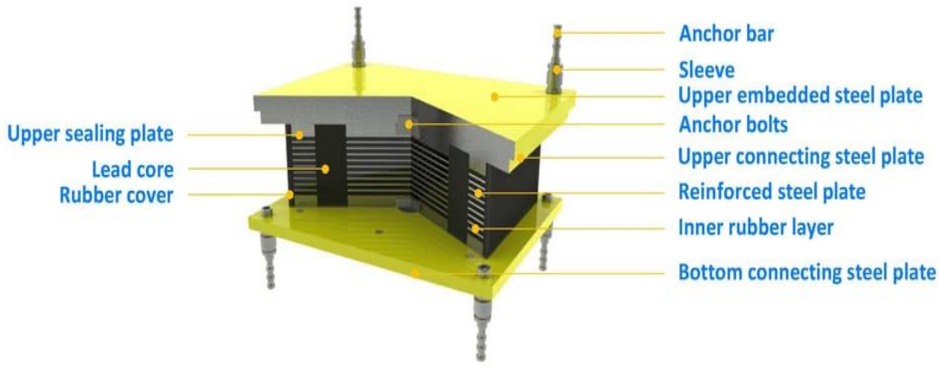

FIGURE (1) LEAD RUBER BEARING

1.1.2) working principle:-

The lead rubber bearing has same mechanical properties with laminated rubber bearing. Besides it has high damping property. As we know the laminated rubber bearing has large displacement deformation in horizontal direction.

In the earthquake, this structure can separate top and bottom. Structure vibration, enlarge self vibration cycle and reduce seismic force. Besides, the lead core will squeezed and yielded during the shear process to dissipate seismic force. After the earthquake, the lead rubber bearing can help the building restore the normal position through dynamic recovery and recrystallization of lead core and shear strain of laminated rubber bearing.

Vertical loading transfer process:-

Beam →top embedded steel plate→ top connecting steel plate→ top sealing steel plate→ laminated rubber bearing with lead core structure→ bottom sealing steel plate→ bottom connecting steel plate→ pier.

Horizontal loading transfer process:-

Pier→ bottom anchor bolt→ bottom connecting steel plate→ top sealing steel plate and shear tenon→ top connecting steel plate→ top embedded steel plate→ anchoring components.

1.1.3) Function of lead core bearing pad:-

Top and bottom plate: - transfer loading and constraint deformation of lead core.

Lead plug: - dissipate energy and decrease displacement.

Steel reinforcing plate: - increase vertical stiffness and constraint deformation of lead core.

Internal rubber bearing: - support structure weight; accommodate rotation and displacement, recovery moving bearing to the original position.

Rubber cover: - protect reinforced steel plate and rubber layers.

1.1.4) Specifications:-

- Shear modulus - 0.8 to 1.2 mpa.
- Working temperature - – 25˚C to + 60˚C.
- Lead core quantity - single or multiple.
- Technical parameter - rectangle and round.

1.1.5) applications:-

LRB, main branch of seismic isolation system is widely applied to the large sized structure such as multi-storey building, Road Bridge, Rail Bridge, and nuclear power station to minimize damage from dynamic loads like earthquakes.

2.1 Design of Lead Rubber Bearing for Symmetrical Building

The calculation of lead rubber bearing is carried out as follows:

1. The first step is to decide the minimum rubber bearing diameter depending on vertical reaction. This maximum vertical reaction obtained from analysis

Result of fixed base building which is found to be 2491 kN is considered as supporting weight LRBs.

2. Second step is to set the target period T_a = 0.961 (calculated as per is code) and the effective damping β is assumed to be 5% for reinforced concrete structure according to IS 1893:2016,clause 7.6.2(a)

3. In third step, the spectral acceleration (s_a =13.88) from the response spectrum graph in relation with the desired period.

4. In the next step design displacement is calculated

$D_d = \frac{g\, c_{vd}\, T_a}{4(\pi)^2\, \beta_d} = \frac{9.81*0.32*0.961}{4*3.141*3.141*1}$ = 0.07641 m.

Where,

s_a = spectral acceleration

T_a = Target period

D_d = Design displacement of isolator

5. The required stiffness to provide a T_a period is the effective stiffness:

$K_{eff} = \left(\frac{2\pi}{T_a}\right)^2 \frac{W_i}{g} = \left(\frac{2*3.141}{0.961}\right) * \left(\frac{2*3.141}{0.961}\right) * \frac{2491.34}{9.81}$ =10856.177 KN/M.

Where,

T_a = Effective fundamental period of the superstructure corresponding to horizontal translation, the superstructure assumed as a rigid body

W_i= The weight on the isolator i.e. maximum vertical reaction

K_{eff} = Effective stiffness of the isolation system in the principal horizontal direction under consideration, at a displacement equal to the design displacement (Dd)

6. E_D = Dissipated energy per cycle at the design displacement (Dd)

$E_D = 2K_{eff\,(Dd)\,2}\beta$ =2*10856.177*0.07641*0.07641*0.05 =19.91 KN-M.

Where,

β = Effective damping

7. Q= Force at design displacement (Q) under cyclic loading

Q= $\frac{E_D}{4d_d} = \frac{19.91}{4*0.07641}$ =65.15 KN.

8. Pre-yield in rubber $K_2 = K_{eff} - \frac{E_D}{D_d}$ =10856.177 - $\frac{65.145}{0.07641}$ =10003.53 KN/M.

9. Post – yield stiffness (for non-linear) $K_1 = K_2$ *10 =100035.5 KN/M.

10. Post - yield stiffness ratio (n) = $\frac{K_2}{K_1}$ = 0.1

11. Yield displacement (distance from end J), (Dy) = $\frac{Q}{K_1 - K_2} = \frac{65.15}{100035.3 - 10003.53}$ = 0.00723 m.

12. Total thickness of LRB $(t_r) = \frac{D_d}{\gamma}\ \frac{0.07641}{1.5}$ = 0.0509 m

13. $D_{bearing}$ = Diameter of lead rubber bearing

$$D_{LRB} = \sqrt{\frac{K2tr}{400\pi}} = \sqrt{\frac{10003.53*0.0509}{400\pi}} = 0.636 \text{ m.}$$

Where,

D_{LRB} = Diameter of lead rubber bearing

t_r = Total thickness of Lead-rubber bearing thickness

12. Total loaded area (A_L) calculation

- D_{LC} = Diameter of lead core of LRB

$$D_{LC} = \sqrt{\frac{4Q}{\pi\sigma_{pb}}} = \sqrt{\frac{4*65.15}{\pi*11000}} = 0.0868 \text{ m.}$$

Where,

σ_{pb} = Total yield stress in lead, it is assumed to be 11 mpa

• Area of lead core in LRB

$$A_{LC} = \frac{\pi}{4} \times \left(D_{pb}\right)^2 = \frac{\pi}{4} \times (0.0868)^2 = 0.00591(M)^2.$$

- D_{ff} = Diameter of force free section = D_{LRB} – 2 tr = 0.636 – 2*0.0509 = 0.5342 m.

• A_{ff} = force free area

$$= \frac{\pi}{4}\left(D_{ff}\right)^2 = \frac{\pi}{4}(0.5342)^2 = 0.2241(M)^2$$

• A_L = Total loaded area

= Force free area – Area of lead core

= 0.2241 – 0.00591 = 0.2181$(M)^2$.

13. Circumference of force free section

$C_f = \pi \times tr \times D_{ff}$ = 3.141*0.0509*0.534 = 0.0854 m.

14. S = Shape factor

$$= \frac{\text{loaded area}}{\text{circumferance of force free section}}$$

$$= \frac{A_L}{C_r} = \frac{0.2181}{0.0854} = 3$$

S = 3

15. H= Total height of LRB

= (N× t) + (N – 1)t_s + 2t_{ap}

N = $\frac{0.2}{t}$ = $\frac{0.2}{0.053}$ = 4.

H = 4 * 0.053 + 3 * 0.0025 +2 * 0.003 = 0.2255 m.

Where,

N = No. of rubber layer

t = Single rubber layer thickness = $\frac{D(lrb)}{4*S}$ = 0.053 m.

t_s = Thickness of steel lamination (2.5 mm) =0.0025m.

t_{ap} = end plate thickness, take 19mm to 38mm, choose -30mm. = 0.003 m.

16. Bearing horizontal stiffness (K_b)

K_b = $\frac{G\ A_r}{H}$ = $\frac{0.7*1000*0.2181}{0.2255}$ = 677.02 KN/M.

Where,

G = shear modulus (varying from 0.7 to 1.2 Mpa)

Adopting 0.7 Mpa

17. Total bearing vertical stiffness

K_v = $\frac{GS_i^2 A_r k6}{(6GS_i^2+k)H}$ = $\frac{0.7*1000*9*0.2181*2000000*6}{(0.7*1000*9*6+2000000)*0.2255}$ = 35881.39 KN/M.

k = rubber compression modulus = 2000 Mpa

18. Yield strength (Fy) = Q+K_2 Dy = 65.15 + 10003.53*0.00723 = 72.38 KN.

19. Bonded area (D_1) = 586mm.

20. Rotational inertial (I) =$\frac{\pi}{64}$ $(D_1)^4$ = $\frac{\pi}{64}$ $(0.586)^4$ = 0.005788 km/m.

21. Cover from lead to end plate = 25mm.

22. Bonded diameter = 586mm.

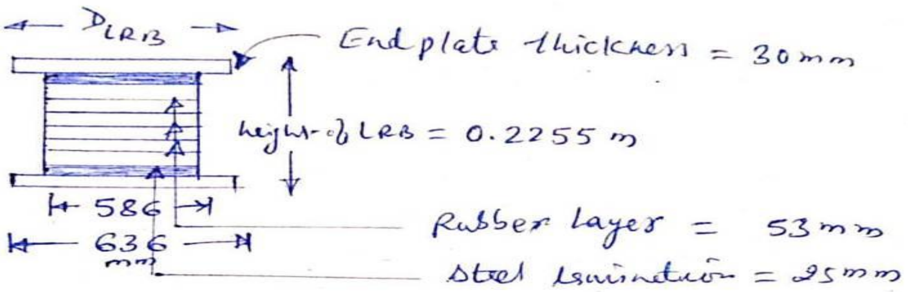

fig (a) : Designed parameters for Lead Rubber bearings

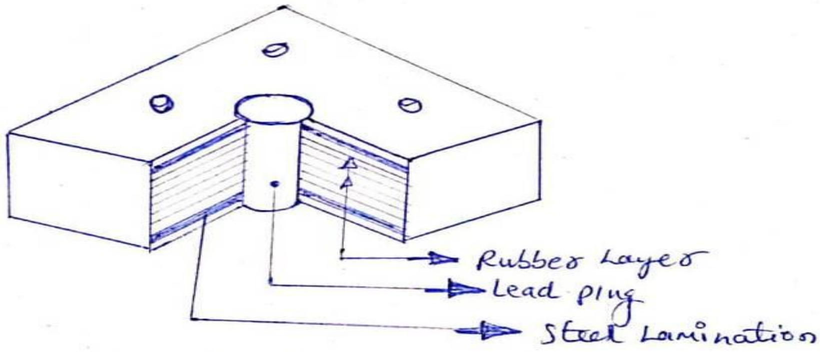

fig (b) : Section of Lead Rubber bearing

FIGURE (2) INTERIOR VIEW OF LRB

2.1.2) TABLE -1: SUMMRY OF LRB PARAMETRES FOR SYMETRIC BUILDING:

1. Rotational inertia (I)	0.005788 kN/m
2. U_1effective stiffness	1085617.7 kN/m
3. U_2/U_3effective stiffness	10856.177 kN/m
4. distance from end (J)	0.000723 m
5. U_2/U_3 stiffness	100035.3 KN/M
6. U_2/U_3 yield strength	72.38 KN
7.stiffness ratio(n)	0.1

2.2) Modelling and Analysis of fixed base and Isolated base Symmetrical Building Model

The main objective of work is to reduce dynamic properties of structure by providing energy dissipations. Thus from above design of Lead Rubber Bearing data a Base Isolated symmetric building model is created and analyzed by using E-TABS software. The assumed preliminary data required for analysis of frame is shown in Table 2. The three dimensional view of created model of base isolated building and fixed base buildings is as shown in Figure 2 .

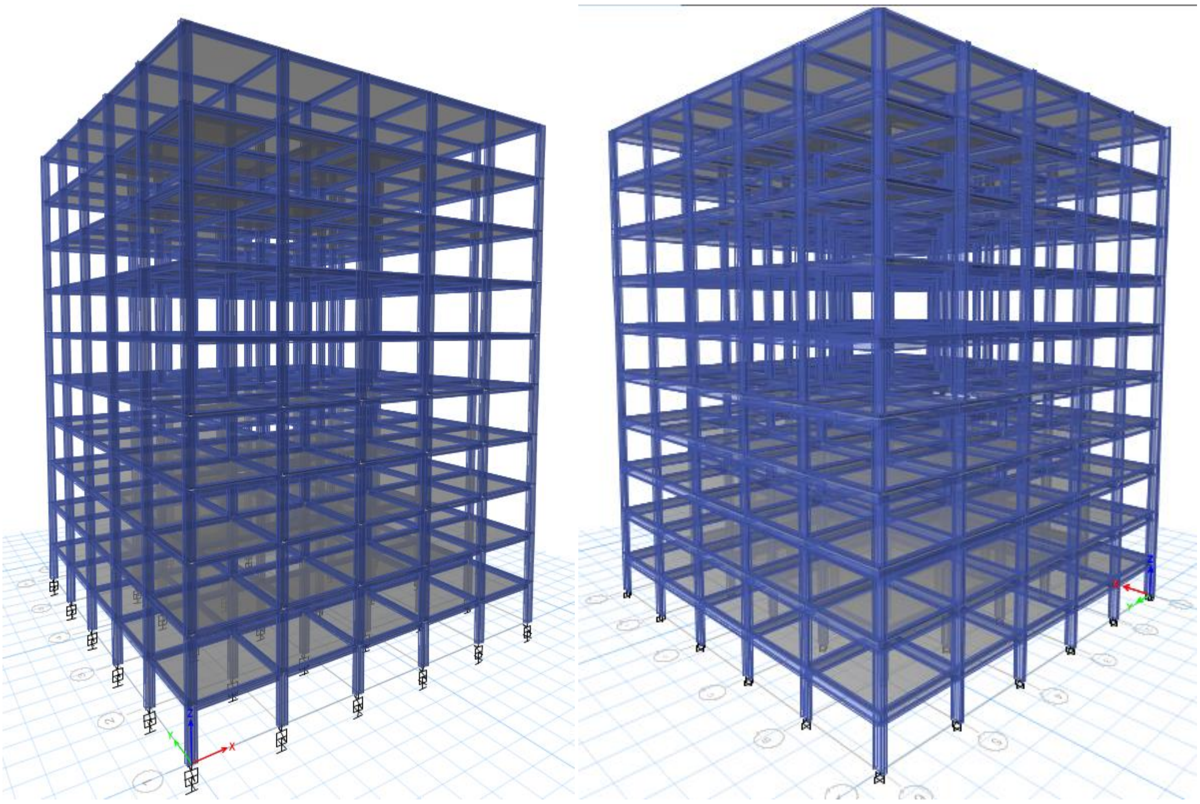

FIGURE (3): FIXED BASE AND ISOLATED BASE MODEL

Table -2, the preliminary required data:-

1	Type of structure	Multi-storey rigid jointed plane frame (Special RC moment resisting frame)
2	Seismic zone	III
3	Zone Factor	0.16
4	Number of storey	G+9
5	Floor Height	3 m
6	base floor height	2.5m
7	Infill wall	225 mm thick wall
8	Impose load	2.5 kN/m2
9	Materials	Concrete (M25) and Reinforcement Fe500
10	Size of column	300 mm x 500 mm
11	Size of beam	200mm x 300 mm
12	Depth of slab	127mm
13	Specific weight of	25 kN/m3

	RCC	
14	Specific weight of infill	20 kN/m3
15	Type of soil	Rock
16	Response spectra	As per IS 1893 (part 1):2002
17	Load Combinations	As per IS 1893:2002
		1) 1.2(DL + LL)
		2) 1.2DL + EL)
		3) 1.2DL + LL + EL)
19	Response Reduction Factor (R)	5 (SMRF)
20	**(I)**	1

Table – 3 analysis result of fixed base symmetric building:-

Sr. No.	Building Parameter	Result
1.	Maximum Storey Drift	0.003919 (at storey-3 for RSA)
2.	Maximum Storey Acceleration	0.272m/s^2
3.	Base Shear	1066.904 kN (X-Direction) 970.567 kN(Y-Direction)
4.	Maximum Lateral Displacement	74.75 mm

Table-4 analysis result of isolated base symmetrical building:-

Sr. No.	Building Parameter	Result
1.	Storey Drift	0.002973 (at storey -1 for RSA)
2.	Storey Acceleration	0.189m/s^2
3.	Base Shear	385.8177kN (X-Direction)
		380 kN (Y-Direction)
4.	Storey Displacement	36.024 m.

2.3) Observation and results:-

(1) Storey Shear:-

Maximum storey shear in fixed base and base isolated symmetric building as shown in Figure 1. From Figure 1, it is observed that for symmetric building with maximum amplitude value in base isolated building is decreased by 36% in X-direction while 39% in Y- direction in compression to fixed base models.

Base Shear for Symmetric Buildings

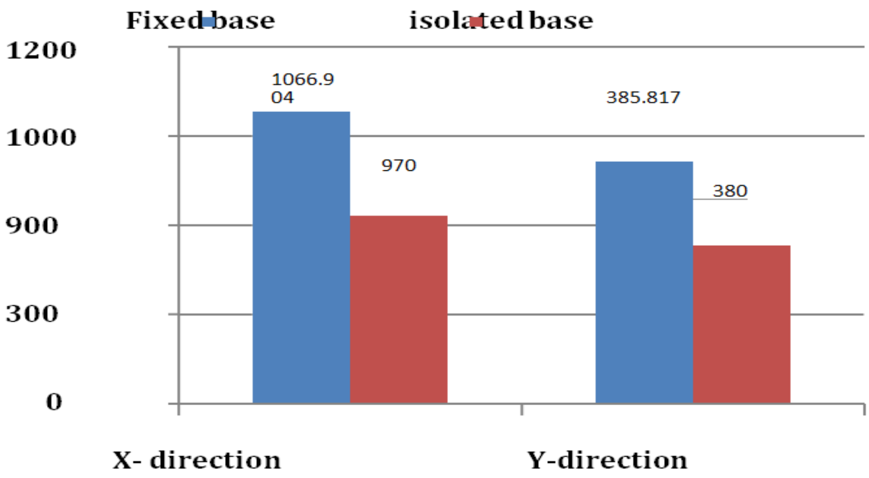

Figure (4) base shear on fixed and isolated building

(2) Storey Drifts:-

The floor level Vs storey drifts graph models of fixed and isolated base building for symmetric building are as shown in Figure 5 and 6. From Figure 5 and 6, it is observed that the base isolated building storey drifts are significantly reduced in comparison with the corresponding fixed base model Figure (5) storey drift for isolated base building

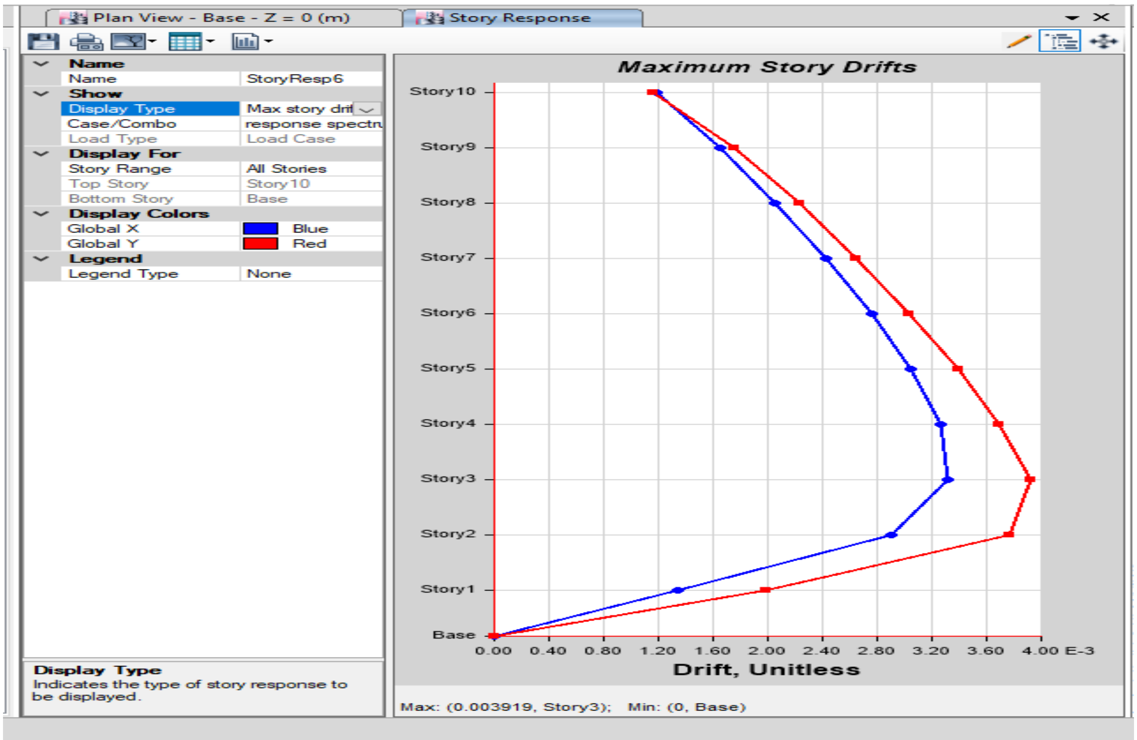

Figure (4) storey drift for fixed base building

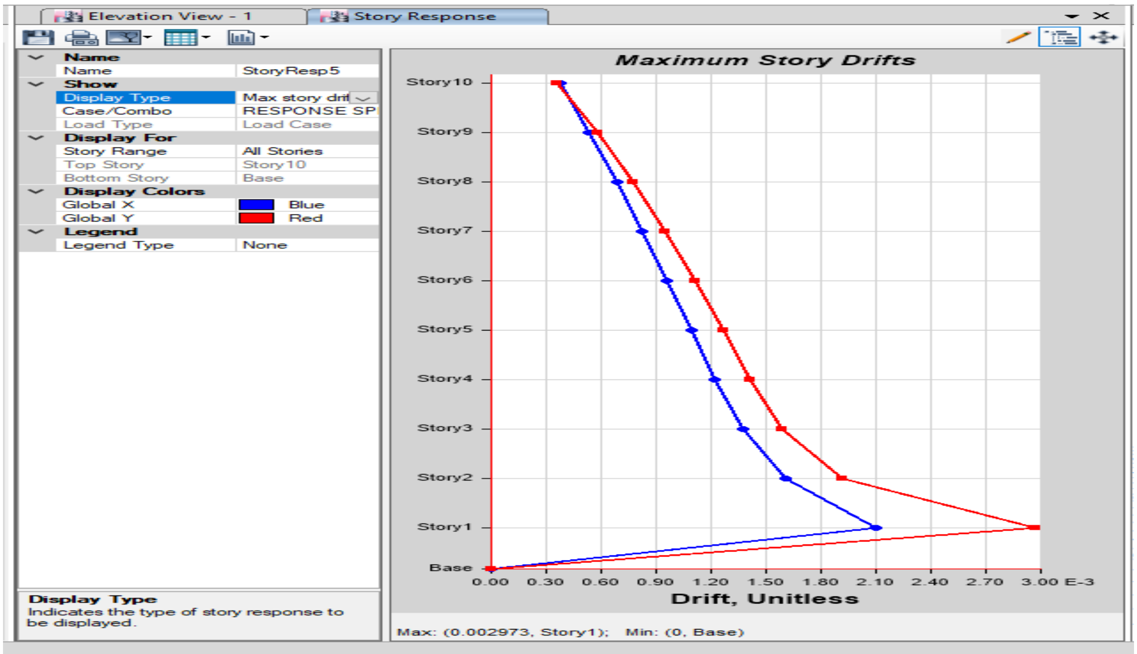

Figure (5) storey drift for isolated base building

(3) Lateral Displacement:-

The floor level Vs lateral displacements graph of models of fixed and isolated base symmetric building for are as shown in Figure 6 and 7 respectively. From Figure 6 and 7, it is observed that in base isolated building the lateral displacements are observed less as compared to fixed base building.

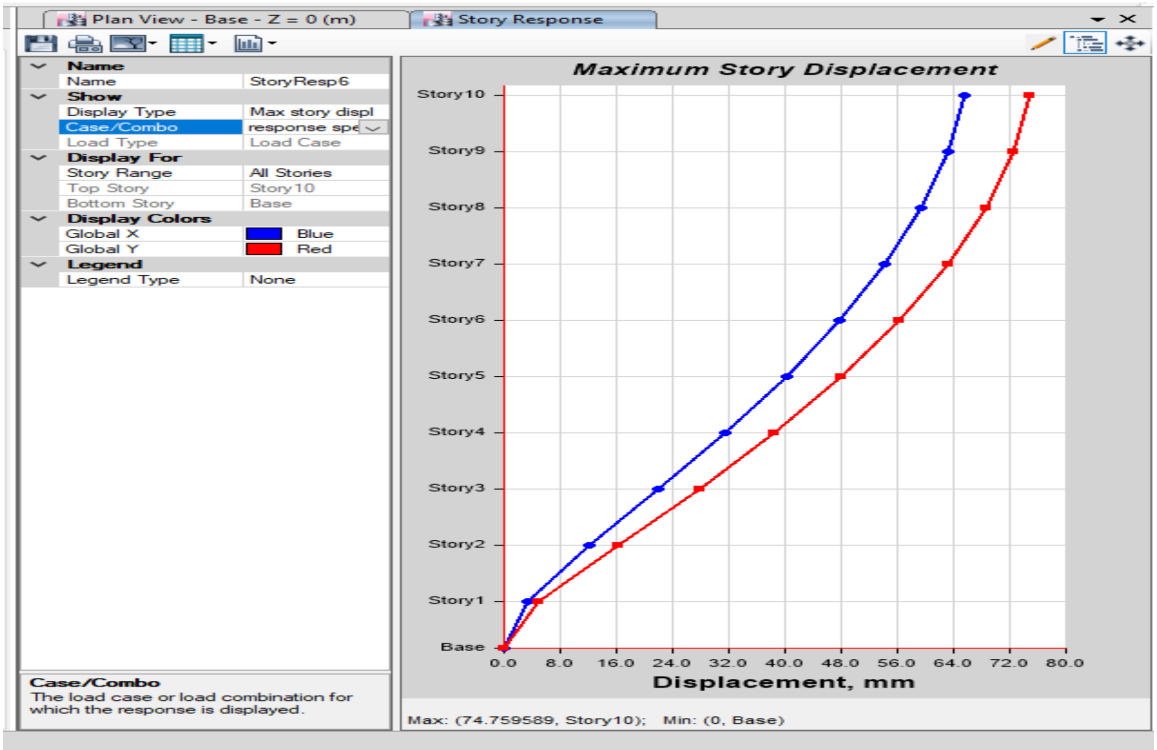

Figure (6) lateral displacement for fixed base building

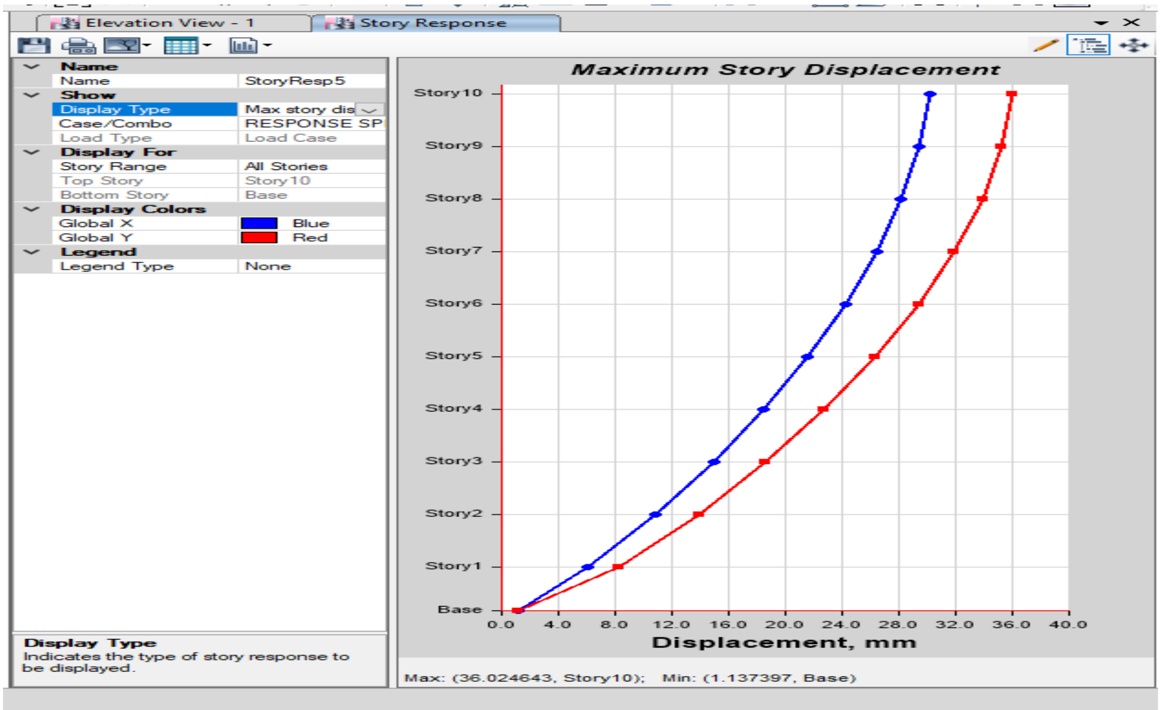

Figure (7) lateral displacement for isolated base building

(4). storey Acceleration

The storey acceleration of fixed and isolated building for symmetric with X and Y Directions are 0.272 and 0.189 respectively. There is large difference in storey acceleration for fixed base building model from bottom to top storey. In base isolated model the storey accelerations are nearly same from bottom to top storey.

CONCLUSION: From analytical results, it is observed that the energy dissipation technique is very significant in order to reduce the seismic response of symmetric models as compared to fixed base building and control the damages in building during strong ground shaking. By comparing the dynamic properties of buildings following conclusions are made:

1. It has been observed that storey acceleration, storey shear , lateral displacements were observed for building are gradually decreases for top storey of base isolated building as compared with fixed base building model.
2. From the analysis result, it is observed that the storey drift is more at storey- 3 while less in storey -1 on both models of symmetric building.
3. It has been observed that as floor height increases, lateral displacements increases drastically in fixed base building as compare to base isolated building. Due to this reduction in lateral displacement during earthquake damages of structural as well as non structural is minimized.
4. In both of the models fixed base and base isolated there is reduction in bending moment. Thus it will require less reinforcement. Therefore cost is reduced considerably.

REFERENCES-

1) seismic design and evaluation of moment resisting frames using elastomeric dampers, christos a. basagiannis, a thesis submitted to the degree of doctor of philosophy
university of oxford 2018.
2) seismic analysis of fixed based and base isolated building structures ms. minal ashok somwanshi† and mrs.rina n. pantawane asst. professor, department of civil engineering, jawaharlal darda institute of

engineering and technology, yavatmal, maharashtra, india accepted 22 july 2015, available online 28 july 2015, vol.3 (july/aug 2015 issue).

3) design of base isolators for a 5-storeyed building with isolator's analysis in abaqus, Jaypee University of Information and Technology Waknaghat, Solan –173234, Himachal Pradesh may 2015.

4) response of lead-rubber bearing isolated structure radmila b. salic 1, mihail a. garevski 2 and zoran v. milutinovic 3 ,The 14th World Conference on Earthquake Engineering October 12-17, 2008, Beijing, China.

5) study of lead rubber bearings for vibration reduction in high-tech factories, Shen-Haw Ju * , Cheng-Chun Yuantien and Wen-Ko Hsieh Department of Civil Engineering, National Cheng Kung University, Tainan 70101, Taiwan; sunny21208@gmail.com (C.-C.Y.); eric3320jh@gmail.com (W.-K.H.).

6) dynamic analysis of the base isolated tubular tall building system (lead rubber bearing) in etabs, international journal of civil engineering and technology (ijciet) volume 10, issue 04, april 2019, pp. 1203–1210, article id: ijciet_10_04_126available online http://www.iaeme.com/ijmet/issues.asp?jtype=ijciet&vtype=10&itype=4 issn print: 09766308 and issn online: 0976-6316

7) dynamic analysis of multi-storey building under seismic excitation by response spectrum method using etabs, usep: journal of research information in civil engineering, vol.14, no 4,2017.

8) Seismic and Time History Performance of RCC Framed Buildings with and without Passive Energy Dissipator International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-9 Issue-3, February, 2020