IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

"Analysis Of Multistory Rc Frames Structure Using X-Bracing, Base Isolator And Damper"

[1]Sameershaha Gulamali Rafai, [2]Ganesh Chandrakant Jawalkar, [3]Shrishail Basavraj Tanawade.

[1]Post Graduate Student, Department of Civil Engineering,[2]Associate Professor,[3]Associate Professor.
Civil – Structural Engineering Department,
N.B. Navale Sinhgad College Of Engineering Solapur - 413255, State-Maharashtra, India

Abstract:Effect of earthquake can be very hazardous to the structure influenced by these forces. There are many traditional methods for protection of structure against earthquake effects. But there are some disadvantages in these methods. Increasing strength and stiffness are some of the traditional methods. But they lead to higher sections and result in uneconomic design. To overcome these disadvantages associated with the traditional method, many vibration-control measures, called structural control, have been studied and remarkable advances in this respect have been made over recent years. This paper describes the effect of use of steel bracing, dampers, base isolator (lead rubber bearing), combination of steel bracing with dampers and the combination of base isolator with steel bracing in a structure subjected to earthquake motion. The structure is designed in ETABS 2016 and then bracings, dampers, base isolator and some combinations are applied respectively in 6 different models and results are compared. Force of ground motion that is earthquake force is applied to structure by using seismic coefficient method. Base isolated structure gives improved performance against seismic vibrations than conventional structure. The essential characteristics of base isolation system are isolation, energy dissipation, and restoring mechanism. It is shown that under design conditions, all base isolators can significantly reduce the acceleration transmitted to superstructure. Bracing and dampers are also useful reduction of storey drift and base shear.

***Key Words*:** RCC, Bracings, Dampers, Base Isolators, Seismic Coefficient Method, Storey Displacement, Storey Drift, Base Shear, Lead Rubber Bearing, Time Period**.**

I. Introduction

For seismic design of building structures, the traditional method, i.e., strengthening the Stiffness, strength, and ductility of the structures, has been in common use for a long time. Therefore, the dimensions of structural members and the consumption of material are expected to be increased, which leads to higher cost of the buildings as well as larger seismic responses due to larger stiffness of the structures. Thus, the efficiency of the traditional method is constrained. To overcome these disadvantages associated with the traditional method, many vibration-control measures, called structural control, have been studied and remarkable advances in this respect have been made over recent years. Structural control can be classified into active control, passive control, hybrid control, semi-active control. Base isolation is passive control.

Ameya A. Japtiwale **[1]**(2022) "A Review on Base Isolation of Multi-storied Steel Structure"It mainly utilizes the motion of the structure to develop the desired control forces. After reviewing this entire project, it can be concluded that base isolated structure gives improved performance against seismic vibrations than conventional structure. In base isolated structures, the decrease in formation of plastic hinge formation is more than in fixed base structures. **Santoshi N Mohitkar[2]** (2020) "Analysis of RC Building Using Base Isolation and TM Damper System" The study was carried out for RCC building in ETAB software using High Density Rubber Bearing (HDRB) & Frictional Pendulum System (FPS) isolators and Tuned Mass Damper (TMD).This RC building was modeled with different structural control system such as High

Density Rubber Bearings, Friction Pendulum System and Tuned Mass Damper with use of commercial computer software ETAB. After that various ground motion data was applied to the building model to evaluate structural response. The numerical data for (G+20) storey RCC buildingsthe results obtained from analysis were base shear and Storey drift it is greatly reducing by use of FPS over HDRB and TMD. Also concluded that FPS gives maximum base displacement compared to HDRB and TMD. **Mohit Kumar Prajapati[3]**(2020), "Analysis of Multi-Storey RC Frame Irregular Step-Up Structure with Fixed Base and Using Base-Isolation Damper Support in High Seismic Zone" in this literature The structure was an Irregular G+7 RC Frame Multi-storey building. The structure was irregular along the height possess vertical irregularity. The structure was considered to be in high seismic Zone V with damping ratio (ξ) of 5%. The cases taken here is an irregular structure with step-up at storey-6 which is having fixed-base support is compared with the same irregular structure with step-up at storey-6 having base-isolation (LRB). The Dynamic analysis approach was used for the study of response of the structure and design by RSA (Response Spectrum Analysis). **Y. Rajesh Kumar [4]**(2018) "Comparative Study Of Base Isolators and Viscous Fluid Dampers On Seismic Response Of Rc Structures"these study aims to understandingthe seismic response of R C structures of varying floor levels when subjected to an earthquake ground motion such as Electro by using base isolation and fluid viscous dampers as vibration control system and a comparative study is made between the two vibration control systems. Models of varying floor levels of 5,8,12 and 15 which are fixed base structures were considered in the study and modal time history analysis is performed using ETABS software It has been observed that base shear decreased largelyto an extent of 96%, lateral roof displacement increases to an extent of 45% in base isolated structure where as base shear decreased to an extent 38%, roof displacements decreased to an extent of 71% in structures with viscous dampers when compared to bare frame structures.**Wen, Baifeng [5]** Put forward based on codes (seismic code, 2001) computer software based on above method with user friendly interface, pre-processor, and post-processor was developed for practical engineering design of superstructure and foundation. **Murnal [6]** To overcome the various limitations the author have recently developed a new isolation system called the variable frequency pendulum isolator.**Nagajyothi, Ghorpade[7]** studied the design of lead rubber bearing system and high damping rubber bearing system for isolated structure for long periods for 5 storey building. **Rincy M. A [8]** (2016), "Comparative Study of RC Framed Building with Isolator and Dampers" in this LiteratureAnalysis was done by pushover analysis and response spectrum method with the help of finite element software. Comparative analysis of structures with fixed base, structure with damper and structure with isolator were done. Storey displacement, storey acceleration, modal time period, storey drift and performance point were analyzed with the help of software.

From the literature review, it can be concluded that base isolated structure gives improved performance against seismic vibrations than conventional structure. In base isolated structures, the decrease in formation of plastic hinge formation is more than in fixed base structures. The essential characteristics of base isolation system are isolation, energy dissipation, and restoring mechanism. But some isolators like friction type base isolator are effective only under certain excitations and structural characteristics. It is shown that under design conditions, all base isolators can significantly reduce the acceleration transmitted to superstructure.This paper considers the use of bracings, dampers, and lead rubber bearing and comparison of each of this with conventional RCC building. One structure of RCC building is modelled and analysed in ETABs and then each of above mentioned is applied separately for same model and analysed. Then some different parameters are compared, and results are discussed

1.1 Principle of base isolation

.

Basicprinciple of base isolation is that response of a structure is modified such that ground below is capable of moving without transmitting motion to above structure.In other words, principal of base isolation system is to rectify the response of the structure so that the ground can move below the structure without transferring these motions into the superstructure. In an ideal system to achieve this flexibility in buildings this separation would be total. But in the real scenario, it is necessary to have a vertical support to transfer the vertical loads to the base. Base isolation reduces the seismic demand of the structure instead of increasing the capacity of the structure. Basic requirements of the base isolation system are flexibility, damping and resistance to vertical loads. There are many types of base isolator devices which are as follows 1. Elastomeric bearing 2. Roller and ball bearing 3. High damping bearing 4. Lead rubber bearing 5. Curved or pendulum bearing. In this paper we have used lead rubber bearing.

1.2 Properties of lead rubber bearing

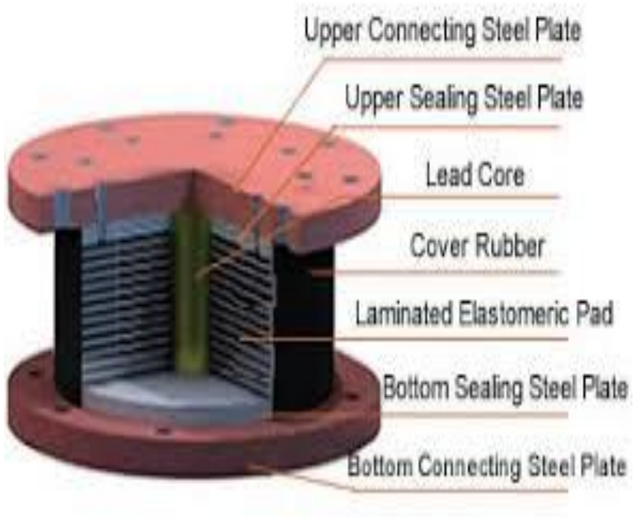


Fig.1- Diagrammatic representation of LRB

LRB isolators have cylindrical rubber bearings, which are reinforced with steel shims. Shims and is placed as alternate layers. Steel plates are also provided at the two ends of the isolator. The steel shims boost the load carrying capacity, thus the structure is stiff under vertical loads and flexible under horizontal loads

2. METHODOLOGY

2.1 Details of the Structure

Details of the structure are as follows

- Plan area: - 400 m^2
- Storey height: - 3 m
- Total height:- 30 m
- Seismic zone: - 5
- Seismic intensity: - very severe
- Zone factor: - 0.36
- Site type: - II (Medium Soil)
- Size of beam :- 0.250 m x 0.450 m
- Size of beam:- 0.400 m x 0.400 m
- Grade of concrete:- M20
- Grade of steel:- Fe 415

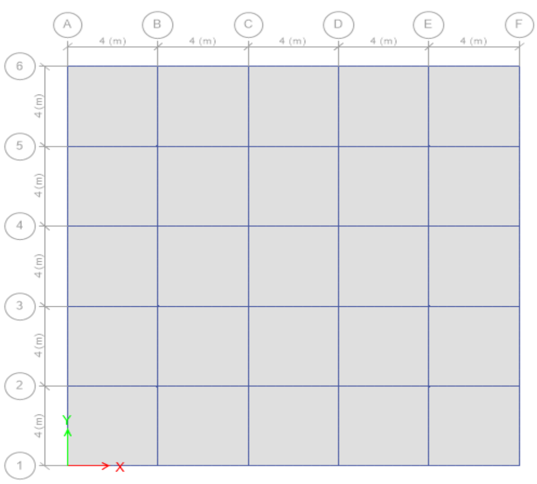


Fig 2 - Plan Of Building

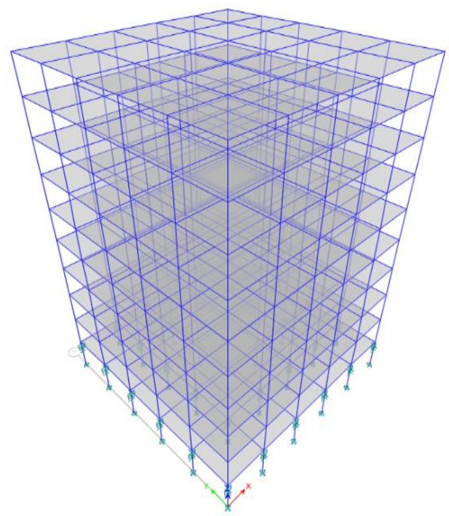


Fig 3 - Elevation Of Building

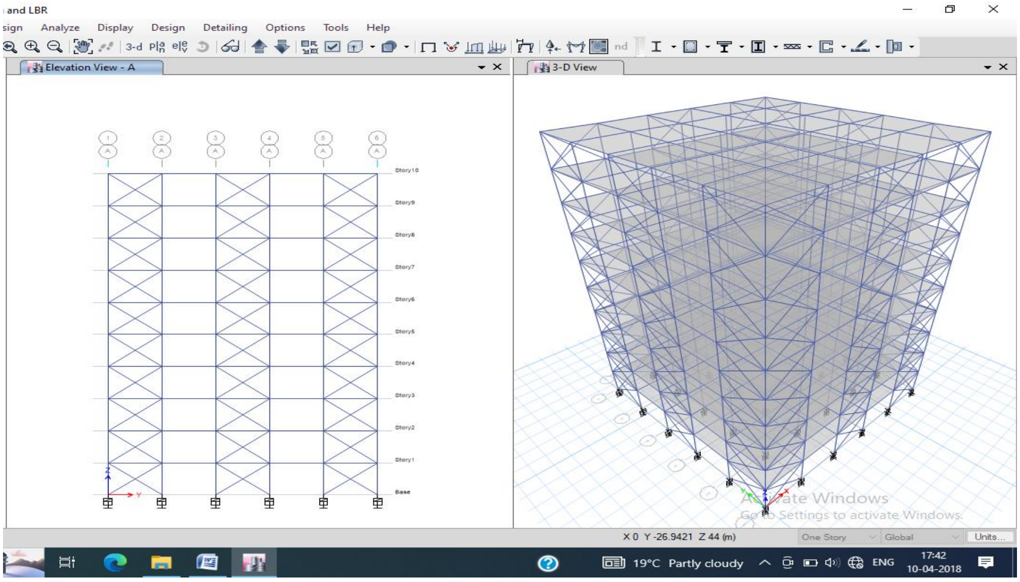


Fig 4 - Front View And Elevation Of Building With X-Steel Bracing

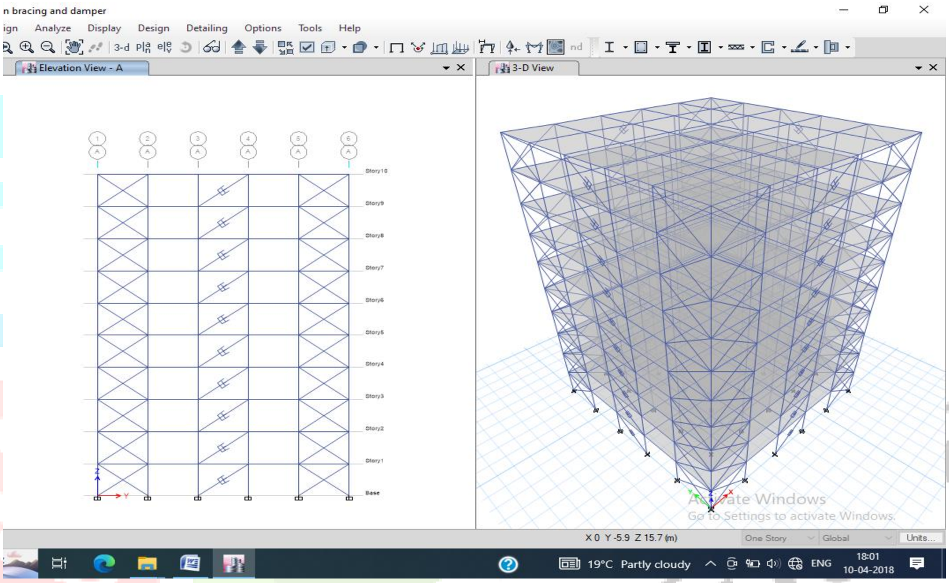


Fig. 5- Front View And Elevation FVD With X Steel Bracing.

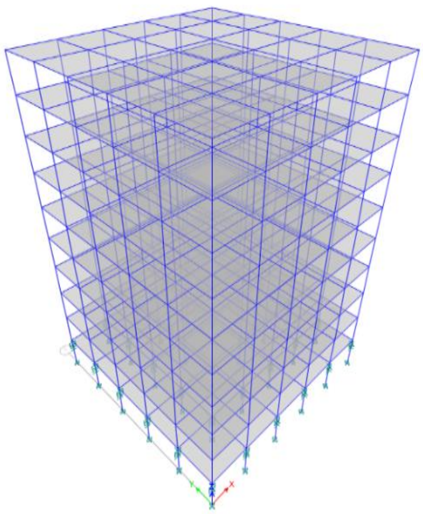


Fig 6 - Elevation of building with LRB

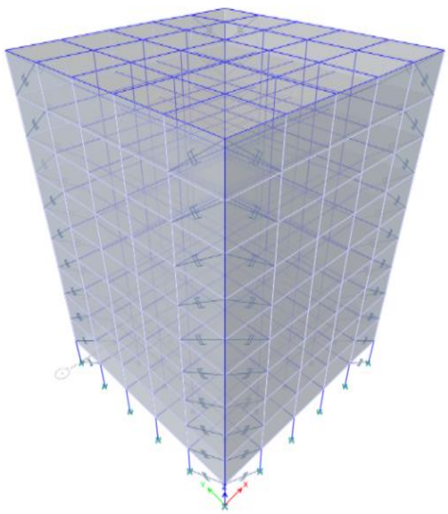


Fig 7 - Elevation of building with damper

2.2 Base Shear Calculation

Storey	W_i (KN)	h_i (m)	$W_ih_i^2$	$K_i = W_ih_i^2 / \Sigma W_ih_i^2$	$Q_i = K_i . V_B$ (KN)
10	1832	30	1.649×10^6	0.219	341.08
9	2290	27	1.669×10^6	0.222	345.28
8	2290	24	1.319×10^6	0.175	272.85
7	2290	21	1.009×10^6	0.134	208.72
6	2290	18	0.742×10^6	0.099	153.51
5	2290	15	0.515×10^6	0.068	106.55
4	2290	12	0.329×10^6	0.0438	68.12
3	2290	9	0.185×10^6	0.0226	38.26
2	2290	6	0.082×10^6	0.0109	17.10
1	2290	3	0.021×10^6	0.0028	4.35
			$\Sigma W_ih_i^2 = 7.520 \times 10^6$	**$\Sigma K_i \sim 1$**	**$\Sigma Q_i = 1555.83 \sim V_B$**

Table 1- Calculation of base shear

Formulae for calculation of base shear from UBC 97 are as follows:

1. Base shear is calculated as –

$$V_B = \frac{C_V IW}{RT}$$

2. Base shear should be less than following value –

$$V_{B_{MAX}} = \frac{(2.5)C_a IW}{R}$$

3. Base shear should be more than following value –

$$V_{B_{MIN}} = \frac{(0.8)zN_V IW}{R}$$

Where, V_B = base shear
W = seismic weight of building
R = response reduction factor
I = importance factor,
T = time period

2.3 DESIGN OF LRB

The formulae for design of lead rubber bearing are as follows:

- Design displacement = $D_D = \frac{g}{4\pi^2} X \frac{C_V T_D}{B_D}$
- Effective stiffness = $K_e = \frac{w}{g} X (\frac{2\pi}{T_D})^2$
- Energy dissipation per cycle = $W_D = 2\pi K_e D_D{}^2 \beta$
- Force at $D_D = Q_D = \frac{W_D}{4D_D}$

- Stiffness in rubber = $K_2 = K_e - \frac{Q_D}{D_D}$
- Yield displacement = $D_Y = \frac{Q_D}{K_1 - K_2}$
- $Q_{D_{required}} = \frac{W_D}{4(D_D - D_Y)}$
- Revised stiffness of rubber $= K_{e_{required}} = K_e - \frac{Q_D}{D_D}$
- Thickness of rubber isolator $= t = \frac{D_D}{\gamma}$
- Area of isolator $= A_{lrb} = \frac{K_{e_{required}} t}{G}$
- Shape factor $= S = \frac{DiameterOfLRB}{4x(ThicknessOf\ \mathrm{Sin}\ gleRubberLayer)} = \frac{d_{lrb}}{4t\gamma}$
- Shape factor $= S = \frac{1}{2.4} x \frac{f_v}{f_h}$
- Compression modulus $= E_c = 6GS^2(1 - \frac{6GS^2}{K})$
- Horizontal stiffness of isolator $= K_H = \frac{G.A_{lrb}}{t_r}$
- Vertical stiffness of isolator $= K_V = \frac{E_C.A_{lrb}}{t_r}$
- Area of hysteresis loop $= A_h = 4Q_D(D_D - D_Y)$
- Yield strength $= F_Y = Q_D + (K_2.D_Y)$

There are some pre requisite parameters which are required for calculation of LRB design. These are as follows:

Damping coefficient $= B_D = 1$,

Seismic coefficient $= C_V = 0.64$, T

ime period = T = 1.566 sec = 2 sec

Calculations-

1. Design displacement $= D_D = \frac{g}{4\pi^2} X \frac{C_V T_D}{B_D}$

$$= \frac{9.81}{4\pi^2} x \frac{0.64x2}{1}$$

= 0.318 m

2. Effective stiffness = $\frac{3245.08}{9.81} x (\frac{2\pi}{2})^2$

$= 3264.797$ KN/ m

3. Energy dissipation per cycle $= W_D = 2\pi K_e D_D{}^2 \beta$

$=(2\pi) x (3264.797) x (0.318^2)\ x\ 0.05$

$=103.719$ KN m

4. Force at D_D $D_D = Q_D = \frac{W_D}{4D_D} = \frac{103.719}{4x0.318} = 81.54$ KN

5. Stiffness in rubber = $K_2 = K_e - \frac{Q_D}{D_D}$

$$= 3264.797 - \frac{81.54}{0.318} = 3008.382$$

6. Yield displacement $D_Y = \frac{Q_D}{K_1 - K_2}$

$$= \frac{81.54}{10K_2 - K_2}$$

$$= \frac{81.54}{9x3008.382}$$

$$= 0.003 \text{ m}$$

7. QD $Q_{D_{required}} = \frac{W_D}{4(D_D - D_Y)}$

$$= \frac{103.719}{4(0.318 - 0.003)}$$

$$= 82.317 \text{ KN}$$

8. Revised stiffness of rubber $= K_{e_{required}} = K_e - \frac{Q_D}{D_D}$

$$= 3264.797 - \frac{82.317}{0.318}$$

$$= 3005.939 \text{ KN/ m}$$

9. Thickness of rubber isolator $= t = \frac{D_D}{\gamma}$

$$= \frac{0.318}{1}$$

$$= 0.318 \text{ m}$$

10. Area of isolator $= A_{lrb} = \frac{K_{e_{required}} t}{G}$

$$= \frac{3005.939x0.318}{0.7x1000}$$

$= 1.366\ m^2$

So, diameter of LRB = d_{lrb} = $\sqrt{\frac{1.366x\,4}{\pi}}$ = 1.32 m

11. Shape factor (S) $= S = \frac{1}{2.4} x \frac{f_v}{f_h}$

$$= \frac{1}{2.4} x \frac{10}{0.5}$$

= 8.33

12. Shape factor $= S = \frac{DiameterOfLRB}{4x(ThicknessOf\ \text{Sin}\ gleRubberLayer)} = \frac{d_{lrb}}{4t\gamma}$

So, thickness single layer of rubber is, $t_r = \frac{1.32}{4x8.33} = 0.04$ m

13. Compression modulus $= E_c = 6GS^2(1 - \frac{6GS^2}{K})$

G = Shear modulus = 0.7 MPa = 0.7 x 10^3 KN/ m^2

S = Bulk modulus = 2000 MPa = 2000 x 10^3 KN/ m^2

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

$$= 6x0.7x1000x8.33^2(1 - \frac{6x0.7x1000x8.33^2}{2000x1000})$$

$= 248966.673\ KN / m^2$

14. Horizontal stiffness of isolator $K_H = \frac{0.7x1000x1.366}{0.318}$

$= 3006.918\ KN/ m^2$

15. Vertical stiffness of isolator = $K_v = \frac{248966.673x1.366}{0.318}$

$= 1069460.614\ KN/ m^2$

16. Area of hysteresis loop (A_h) $= A_h = 4Q_D(D_D - D_Y)$

= 4 x 82.317 (0.318- 0.003)

$= 103.719\ m^2$

17. Yield strength $= F_Y = Q_D + (K_2.D_Y)$

= 82.317 + (3008.382 x 0.003)

= 91.342 KN

The Summary Of Design Of LRB Is As Follows –

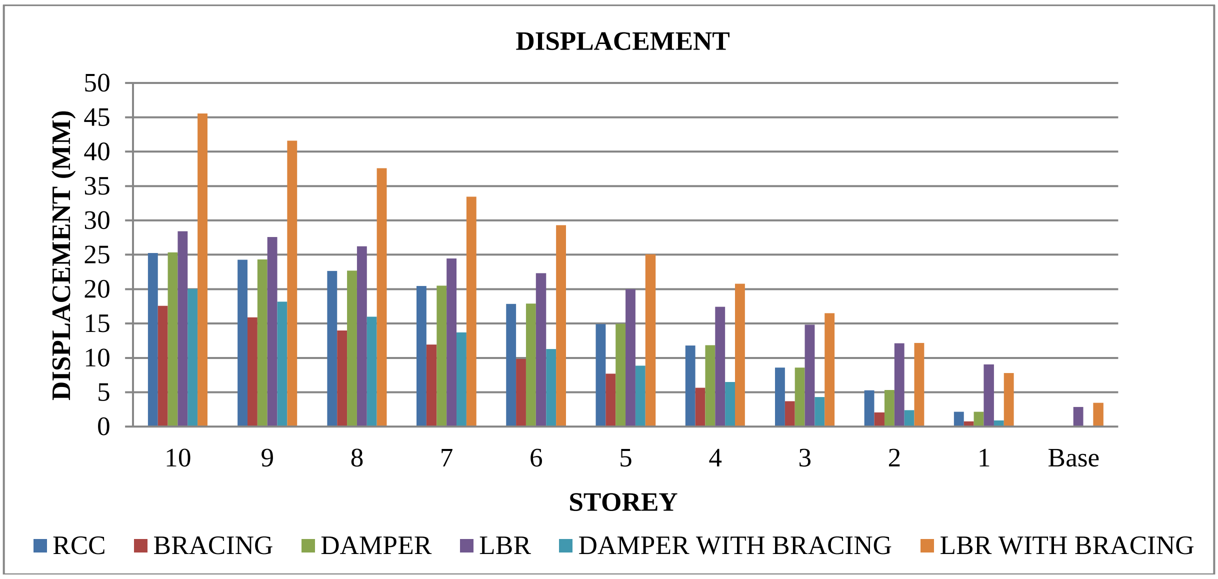
PROPERTY	VALUE
Design Displacement	0.182 m
Effective Stiffness	7702.35 KN/ m
Energy Dissipation Per Cycle	80.152 KN m
Force At D_D	110.100 KN
Stiffness In Rubber	7097.405 KN/ m
Yield Displacement	0.0017 m
Q_D Required	111.137 KN
Revised Stiffness Of Rubber	7091.707 KN/ m
Thickness Of Rubber Isolator	0.182m
Area Of Isolator	1.844 m^2
Shape Factor	8.33
Thickness Of Single Rubber Layer	0.046 m
No. Of Layers	10
Compression Modulus	248966.41 KN/m
Horizontal Stiffness Of Isolator	7092.308KN/ m
Vertical Stiffness Of Isolator	2522494.84 KN/m
Area Of Hysteresis Loop	79.404 m^2
Yield Strength	122.160 KN
Effective Damping	5 %

Table 4.2 - Summary of LRB properties

3. RESULTS

Various parametrs obtained from ETABs were studied and compariosns were made. The obtained results are as shown in the folllowing tables.

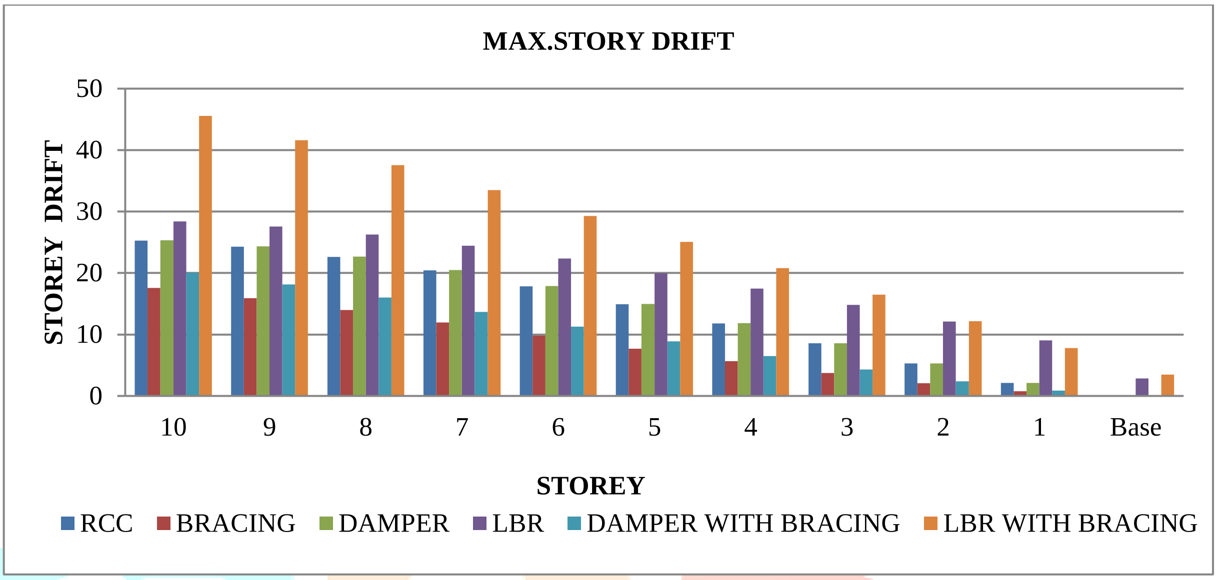
3.1 Maximum Storey Displacement



Graph 1 -Variation of Max Storey Displacement

Maximum storey displacement is increased for building due to bracing with base isolator. This increases the flexibility of structure and increases safety of the structure against earthquake. LBR story displacement value is lesser than the combination of LBR isolator with x-steel bracing, but more than structure with RCC, structure with bracing, structure with damper and combination of bracing and damper

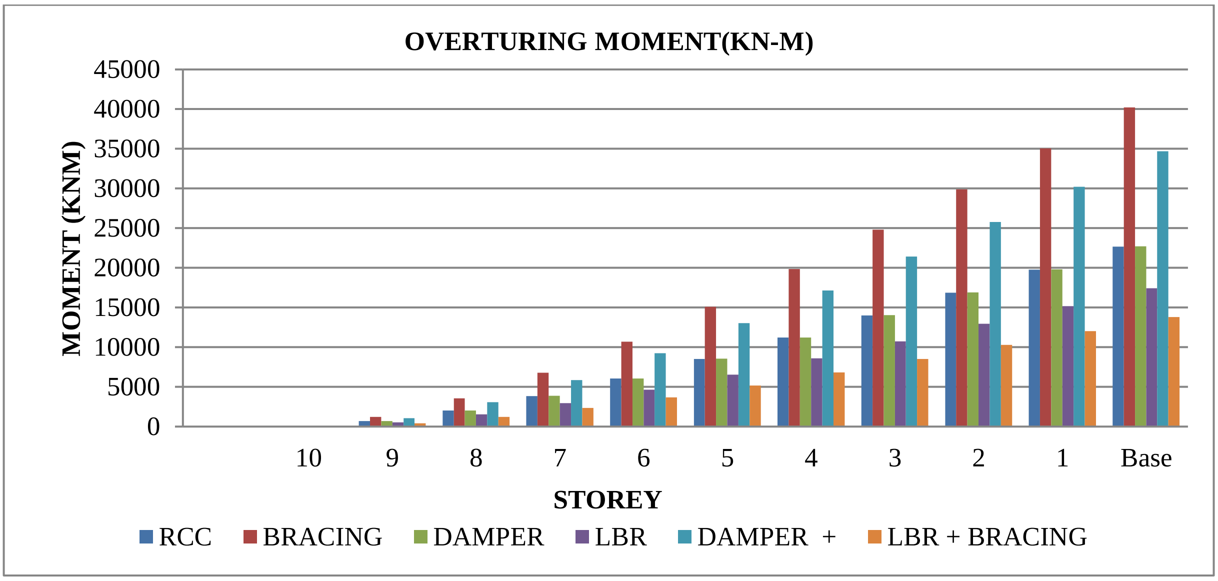
3.2 Storey Drift of Various Models–



Graph 2 -Variation Of Max. Storey Drifts

- Storey drift is reduced due to use bracings in the floors below 6. But in case of lead rubber bearing, that is for base isolated building, storey drift is reduced in all floors except first floor. Story drift is more in case of lead rubber bearing at first floor and in case of bracing the lowest value at first floorIn case of LBR with bracing structure the storey drifts show max values as compare to remaining structures. Reduction of storey drift at top floors is necessary because it is important to reduce the storey drifts of top storey's which damage the structure during earthquake. This improves the performance of building during earthquake.

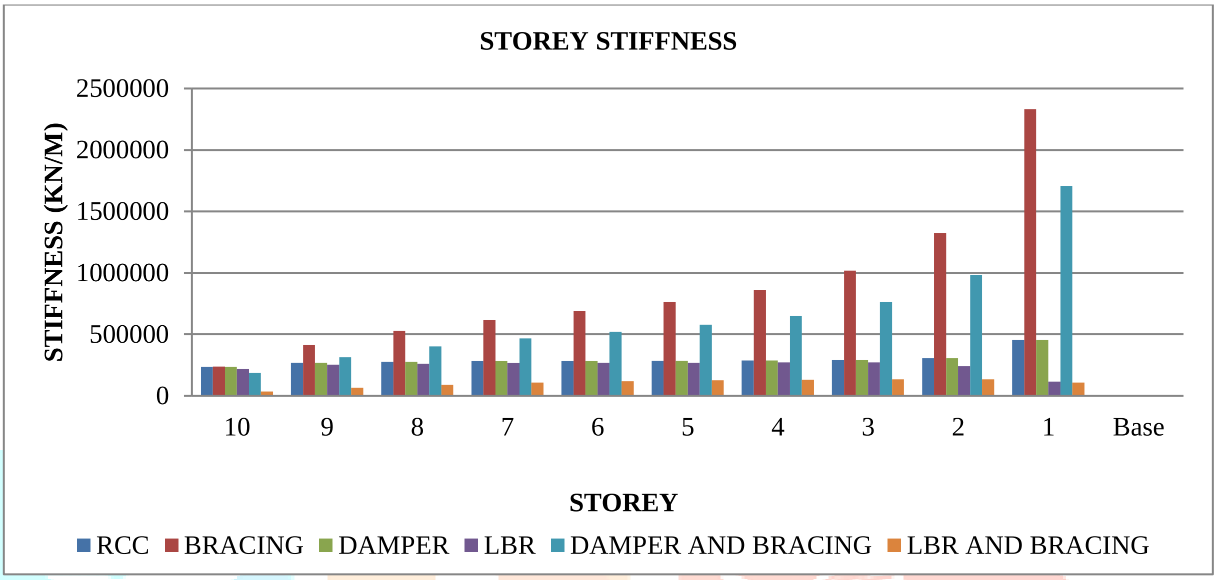
3.3 Overturning Moments of Various Models–



Graph 3 -Variation Of Overturning Moments

Overturning moments are increased for building with backing and damper plus bracing, But overturning moments are approximately same for damper building and more than the lead rubber bearing building and LRB plus bracing, Overturning moments at the base of bracing system is maximum and minimum value at the base of LRB with bracing System. Overturning moments values is maximum at base for each story and minimum at the top storey, which is good and This is satisfactory results.

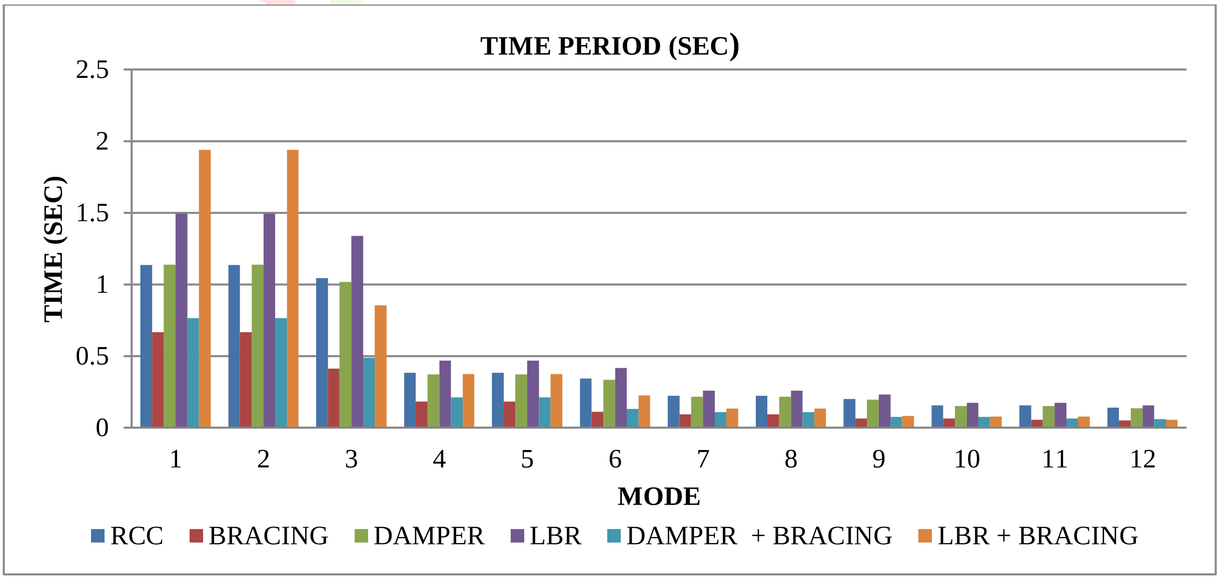
3.4 Storey Stiffness Of Various Models-



Graph 4 -Variation Of Storey Stiffness

Storey stiffness is increased for the building designed with bracings with damper. But is approximately same for damper building,base isolated building and for building with bracing plus LRB stiffness is lesser than RCC building. Base isolator that is plus bracing structure show lesser value of stiffness among the all system.

3.5 Time Period of Various Models–



Graph 5 -Variation of Time Periods

Time period is conisderably increased for combination of bracing with base isolated building and it can be clearly seen from comparison graph between rcc building and the combination of fvd +bracing time period is lesser than the traditional buiding thatis rcc building,but fvd have little bit more rhan the tradistional structure.Time periods is more in case of combination structure LBR with bracing and less in only bracing structure.

4. CONCLUSIONS

1. Use of LRB as base isolator increases the maximum storey displacement of the structure by average of 20%. And with LBR with bracing system give average by more than 70 %. This increases the flexibility of structure and makes the structure stable during earthquake occurrence. And LBR with bracing system give max story displacement among all system.
2. Story drift is reduced by 17% due to use of LRB which gives satisfactory performance during events of earthquakes.
3. Story shear is reduced by 21% due to use of LRB. This makes the structure stable during earthquake. Also story shear is reduced by 39% due to combination of LRB with x steel bracing.
4. Story stiffness is not much affected. It is increased, but with less rate, but it's reduced by 15% due to use of combination LRB with x bracing structures.
5. Overturning moment reduce by 23% due to LRB and 38% reduced by the combination of LRB with use of x bracing.
6. Time period is considerably increased for base isolated building as compare to all other building except combination of LRB with bracing. This increased time period reduces the acceleration and increases the reaction time for structure. This improves the performance of the structure against the earthquake.

REFERENCES

1. Ameya A. Japtiwale,"A Review on Base Isolation of Multi-storied Steel Structure" International Journal for Research in Applied Science & Engineering Technology (IJRASET) *Volume 10 Issue VII July 2022*
2. .Ganapat L. Mathkar ,"Review on Comparative Study of RCC Building by Using Base Isolator of Various Thickness"International Research Journal of Engineering and Technology (IRJET) *Volume: 08 Issue: 06 | June 2021*
3. S.M. Kalantari, H. Naderpour, S.R. HoseiniVaez, "Investigation Of Base Isolator Type Selection On Seismic behaviour Of Structures Including Story Drifts And plastic Hinge Formation", *The 14thWorld Conference on Earthquake Engineering October 12-17, 2008*, Beijing, China.
4. C.P. Providakis, "Effect OfLrb Isolators And Supplemental Viscous Dampers On Seismic isolated Buildings Under Near-Fault Excitations", *Engineering Structures 30 (2008)*
5. Abdo lrahimJalali, Peyman Narjabadifam, "Optimum Modal Characteristics For Multi-Storey Buildings Isolated With Lrbs", *4th International Conference on Earthquake Engineering Taipei, Taiwan, October 12-13, 2006.*
6. A. K. Maurya, V. K. Singh (2018), 'Analysis of Building Using Viscous Dampers in Seismic Zone-V,International Journal of Advances in Mechanical and Civil Engineering, ISSN: 2394-2827, Volum5, Issue-3.
7. Shirule Pravin Ashok , Niraj Mehta , Rahulwagh , Mayur Padhiyar ,Ankesh Samare ,Yogesh Patil(2012)., "Response Spectrum Analysis Of Multi Storied Base-Isolated Building, *International Journal Of Civil, Structural, Environmental And Infrastructure Engineering Research And Development (IJCSEIERD)", Vol.2, Issue 3, Sep 2012 .*
8. Rajesh Chouhan, Sagar Jamle, Kundan Meshram, (2019), "Dynamic Analysis of Tuned Mass Damper Steel Structure: A Review", International Journal of Management, Technology And Engineering, (ISSN: 2249-7455(O)), vol. 9, no. 7, pp. 212-216.
9. Shirule Pravin Ashok , Niraj Mehta , Rahulwagh , Mayur Padhiyar ,Ankesh Samare ,Yogesh Patil(2012)., "Response Spectrum Analysis Of Multi Storied Base-Isolated Building, *International Journal Of Civil, Structural, Environmental And Infrastructure Engineering Research And Development (IJCSEIERD)", Vol.2, Issue 3, Sep 2012 .*

10. Shirule Pravin Ashok , Niraj Mehta , Rahulwagh , Mayur Padhiyar ,Ankesh Samare ,Yogesh Patil(2012)., "Response Spectrum Analysis Of Multi Storied Base-Isolated Building, *International Journal Of Civil, Structural, Environmental And Infrastructure Engineering Research And Development (IJCSEIERD)", Vol.2, Issue 3, Sep 2012 .*
11. A.K.Chopra, D.P.Clough, R.K.Clough "Earthquake resistance of buildings with a soft first storey", International Journal of Earthquake Engg. And Structural Dynamics, Vol. 1, pp. 347-355,1973
12. R.I. Skinner, J.M. Kelly, A.J. Heine "Hysteretic dampers for Earthquake Resistant Structures", International Journal of Earthquake Engg. And Structural Dynamics, Vol. 3, pp. 287-296,1975
13. Lin Su, "Comparative Study of Base Isolation Systems" ,*Journal of Engineering Mechanics*,Vol. 115,No. 9, September, 1989.ASCE, ISSN 0733-9399/89/0009-1976
14. Shirule. P .A, Jagtap. L. P, Sonawane. K. R, Patil. T. D, Jadwanir. N , Sonar. S. K(2011)."Time History Analysis of Base Isolated Multi-Storied Building", International Journal of Earth Sconces and Engineering, ISSN 0974-5904, Volume 05, No. 04.