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Dynamic analysis and Design of G+ 8 storey RC structure by providing lead rubber bearing as base isolation system

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Abstract – *Earthquake is most extreme condition of any building may be required to survive during its lifetime. Seismic base isolation is a simple structural design approach to minimize earthquake damage. These are very stiff in the vertical direction and can carry the vertical load of the building but are very flexible in horizontally, thereby enabling the building move laterally like a rigid mass under strong ground motion. The main purpose of this study is to check the behaviour of the buildings in seismic zone by using lead rubber base isolation concept. and reduce the base shear, displacement and lengthen the period of oscillation due to earthquake ground excitation, applied to the superstructure of the G+8 building by installing lead rubber isolation (LRB) at the foundation level then compare the performance between the fixed base condition and base isolated condition by using SAP software.*

Key Words: *Fixed base, base isolation, lead rubber bearing, Nonlinear Time history analysis, pushover analysis Software SAP2000*

SCOPE OF STUDY

The scope of this study is limited to design of lead rubber bearing for G+8 building. Perform static pushover analysis and nonlinear time history analysis for the Kobe ground motion data. Compare the results with different seismic parameters for fixed base structures and base isolated structures.

1. INTRODUCTION

Base isolation is a passive control system; it does not require any external force or energy for its activation. The term isolation refers to reduce interaction between structure and the ground, when the seismic isolation system is located under the structure; it is referred as "base isolation". It is a system that may be defined as a flexible or sliding interface between a structure and its foundation, for the purpose of decoupling the horizontal motions of the ground from the horizontal motions of the structure. "The principle of base isolation is very simply it changes the response of the building which allows moving the ground below the building so that the earthquake ground motion is not allowed to reached the building".

This improves[9] its response to an earthquake due to additional means of energy dissipation by reducing the transmitting vibrations into the superstructure. Base isolation not only reduces the seismic demand of structure, cost of structure, damages caused during the earthquake but also it enhances the performance of structure under seismic load and after the earthquake , safety of the structure and preservation of property system. The characteristics of proper designed seismic isolation systems should be its flexibility to increase period of vibration and thus reduce force response and energy dissipation to control the isolation system displacement through rigidity under low load levels such as wind and minor earthquakes.

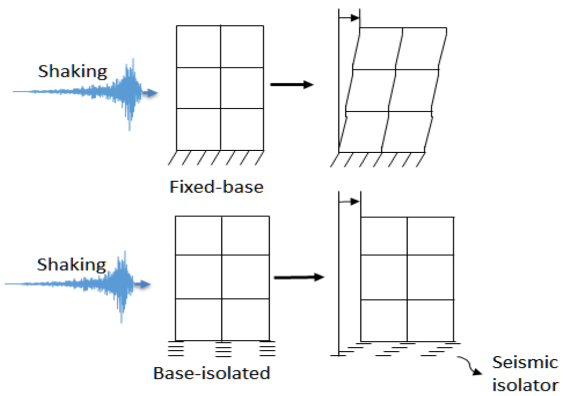

Fig.1 Effect of seismic (base) isolation on the response of a structure.

Lead rubber bearing

Lead rubber bearings were invented in New Zealand in 1975. There are three main pieces of equipment, layers of steel plates, rubber layers and lead core, respectively. The layers of steel provide vertical stiffness and the layers of rubber supply the device with high lateral flexibility. Lead core is the device that will supply extra stiffness to the isolators and appropriate damping to the system.

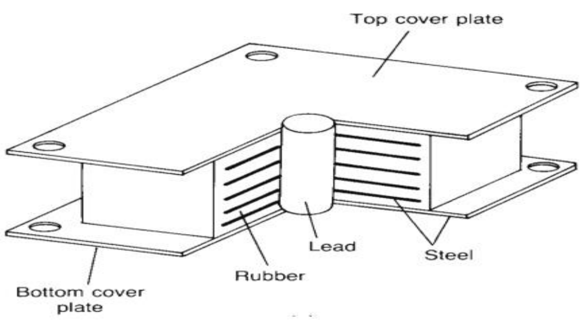

Fig.2 Lead rubber bearing

2. OBJECTIVE OF THE PROJECT

The main objective of project is comparative study of fixed base and base isolated structures by dynamic analysis. The results were compared for Time period, Base shear, and displacements and. The objective of the project is as explained below:

1. To design the lead rubber bearing for G+8 RC frame by using SAP2000.[10]
2. To increase the mode period of the lead rubber isolated structure when compared to conventional building
3. To decrease the base shear and displacement of the lead rubber isolated structure when compared to conventional building [9]
4. To study the effectiveness of providing Lead core rubber bearing for Kobe and superstition ground motion data.
5. Comparative study with different seismic parameters.

3. METHODOLOGY

1. The software used for analysis of a structure is SAP2000
2. The dynamic analysis is carried for structural analysis
3. The codes used are IS 1893 (PART I) 2016, UBC 1997, IBC 2006.
4. Provisions Published by FEMA-451 (Federal Emergency Management Agency) in 2003
5. The building is modelled first then the loads are applied as per code provisions of IS 875 (Part II) Reaffirmed in 2008 for live and dead load.
6. Static pushover analysis and Non linear time history analysis is carried out for the fixed base and lead rubber isolated structures.
7. After the analysis of a fixed base structure the maximum axial load is noted from support reaction results.
8. Then Properties of Lead core rubber bearing are calculated and these properties are used as link properties for base isolation structure.
9. Then the Base Isolation Structure is analyzed and
10. Results are tabulated and discussed.

4. LITERATURE STUDY

Syed Ahmed Kabeer K. I. and Sanjeev Kumar K.S. (2014) in this paper studied how to prevent loss during earthquake by using Base- isolation. The mechanism of the base isolator increases the natural period of the overall structure, and decreases its acceleration response to earthquake/seismic motion. The study is based on to check for the adequacy of the base isolation against earthquake damage when compared to the conventional earthquake resistant design. A building was analyzed using the equivalent lateral force method and response spectrum analysis as fixed base and as isolated base with lead rubber bearing. In this paper they did study for reinforced concrete structures to show the ultimate capacity of the selected bearing system, and to make a comparison for the difference between the isolated base and the fixed base buildings. Finally they concluded lead rubber bearing reduces significantly the displacement, moment and shear generated for the same. {ref.5}

Sameer S. Shaikh and P.B. Murnal.(2015) In this paper A three story building is modeled to compare the response of the structure by using SAP2000. Time history analysis is conducted for the 1994 Northridge and 1940 El-Centro earthquakes. The analysis result shows that when isolator position is shifting it significantly affects the response quantities. It is possible to arrive at optimum location of the isolator so as to get the maximum benefit of base isolation {ref.9}.

Ajai Kumar Rai and Brajesh Mishra.(2017) In this paper studied base isolation techniques, reviews of the current practices and past researches but also need of these techniques by analyzing the earthquake data of the seven prominent cities/districts of the eastern Uttar Pradesh. This has been achieved by evaluating the each city/district by existing civil engineering structures of cultural / historical / archaeological importance, existing & pace of growth of high rise buildings, depth of alluvial soil over the soil/rock, geological, geographical and topographical features and earthquake magnitude.{ref.11}

Venkatesh and Mr.arunkumar.H.R.(2016)In this paper studied the designing of earthquake resistant structure. Earthquake is one of major natural disaster in which many structures damage and collapse due to improper design against seismic motion. Earthquake also affects the economy of the nation, so essential proper measures of prevention must be developed. There are many concepts of designing a building as earthquake resistant structure; the concept studied in this project is base isolation. There are many types of base isolation systems but lead rubber bearing (LRB) is used as base isolation system in this project, LRB is most

widely used as isolation system for buildings. {ref.10}

6. LOADING

Table.1 Seismic details as per IS 1893 Part 1:2016

Sr.No.	Particulars	Description
1	Seismic Zone	III
2	zone factor	0.16
3	Soil type	Type II (Medium)
4	Importance Factors	1.5
5	Response reduction Factor	5
6	Damping of the structure	5%
7	Is code	1893 Part I 2016
8	Time History	Superstition

Table.2 Wind load details as per IS 875 Part 3 1987

Sr.No.	Particulars	Description
1	Wind speed V_b	39 m/s
2	Terrain category	2
3	Importance factor	1.15
4	Risk coefficient (k_1 factor)	1
5	Topography Factor (k_3 factor)	1
6	Wind direction X and Y direction	0^0 &90^0

Live load = 3 KN/m^2, Floor finish =1 KN/m^2

Super dead load - 0.23 X 20 X 3.4 = KN/m^2

7. MODELLING

Table.3 Model Details of G+8 Building

SR.NO.	Particulars	Description
1	Type Of Frame	SMRF.
2	Area	22.5 x 27 sq.m
3	No.of Storey's	G+8
4	Height of storey	4 m
5	Height of building	36 m (class B)
6	flexural members per floor	71
7	Compression members per floor	42
8	No.of slabs per floor	30
9	slab thickness	200 mm
10	Size of column	300 x 900 mm
11	Size of Beam	300 x 600 mm
12	Wall thickness	230 mm
13	Concrete grade	M30
14	Rebar grade	Fe 500, Fe 415

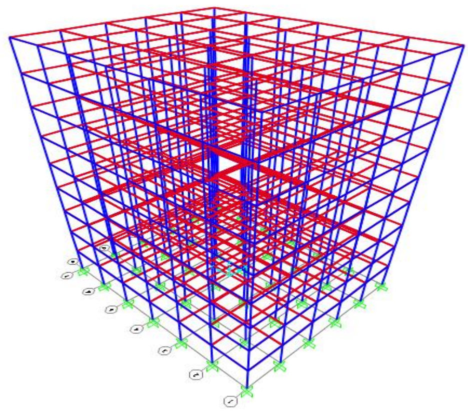

Fig.3 G+8 3D Model

8. ANALYSIS OF MODEL

Non-linear Static Pushover Analysis (NSPA

The method is simple to implement and provides the information about strength, deformation and ductility of the structure as well as the demand. The pushover method applies the analysis under permanent vertical is loads and gradually increasing lateral load.

Time history analysis

Nonlinear time history analysis involves the computation of dynamic response at each time increment with due consideration given to the inelasticity in members. Nonlinear analysis allows for flexural yielding (or other inelastic actions) and accounts for subsequent changes in strength and stiffness.

9. DESIGN OF LEAD RUBBER BEARING

1) Maximum support reaction

After analysis of fixed base building maximum support reaction is noted.

Max. Support reaction = 1015.04 KN

Effective isolation Time period = $2\pi\sqrt{\frac{w}{Ke.g}}$

$$2\pi\sqrt{\frac{1015.04}{1021.2 \times 9.81}} = 2 \text{ sec}$$

2 Calculate design displacement (Dd)

Assume Design time period T_D= 2 sec

$$Dd = \frac{g}{4\pi 2} \times \frac{Cvd.Tb}{B}$$

$$Dd = \frac{9.81}{4\pi^2} \times \frac{0.54 \times 2}{1} = 0.268\ m$$

3. Energy dissipated per cycle (W_D)

$W_D = 2\pi.\text{keff}.\ D_D^{2}.\text{Beff}$

$2\pi \times 1021.2 \times 0.268^2 \times 0.05 \quad = 23.04$KN.m

4. Force at design displacement characteristic

Strength Qd

$$Qd = \frac{Wd}{4D_D} = \frac{23.04}{4 \times 0.268} = 21.5\ KN$$

5 Effective stiffness of isolator (Ke)

$$\text{Keff} = \frac{w}{9} \times \left(\frac{2\pi}{T}\right) x \left(\frac{2\pi}{T}\right)$$

$$\text{Keff} = \frac{1015.04}{9.81} \times \left(\frac{2\pi}{2}\right) x \left(\frac{2\pi}{2}\right) = 1021.2 \text{ KN/m}$$

6 Stiffness in Rubber

$$K_2 = \text{Keff} - \frac{Q}{Dd}$$

$$= 1021.2 - \frac{21.5}{0.268} = 940.97 \text{ KN/m}$$

Where, $\frac{Q}{Dd}$ = stiffness of lead core

7. Yield displacement (DY)

DY $= \frac{Q}{k1-k2}$ we have, k1 = 10 K2..........Thumb rule for lead rubber bearing by J.M Kelly

$$DY = \frac{Q}{10k2-k2} = \frac{Q}{9k2} = \frac{21.5}{9 \times 940.97} = 0.00254m$$

8. Calculation of area and diameter of lead plug yield strength of lead is around 10 Mpa the

Area of lead plug needed for entire isolation is,

$$ApB = \frac{QR}{10 \times 103} = \frac{21.69}{10 \times 1000} = 0.00216\ m2$$

Diameter of lead plug d $=\sqrt{0.0028 \times \frac{4}{\pi}} = 0.053\ m = 53\ mm$=60mm

9. Total thickness of Rubber layer (tr)

tr $=\frac{DD}{V}$ where v = 100% (maximum shear strain of rubber)

$$tr = \frac{0.268}{1} = 0.268\ m$$

10. Area of Bearing

$$ALRB = \frac{\text{keff(R)}\times tr}{G} = \frac{940.26 \times 0.268}{0.7 \times 1000} = 0.359m\ 2$$

11. Diameter of Bearing

QLRB $= A \times \frac{4}{\pi} = 0.359 \times \frac{4}{\pi} = 0.676$m

S = D/4t = 0.646/0.02*4 = 8.45

Provide 20 mm thk 14 rubber bearing

12. Dimension of lead rubber bearing (LRB)

Let, thickness of shim plates be 2.8mm

No. of shim plates = (14-1) = 13

End plate thickness is between 25mm

Total height (rubber+ shim + end plates) = 0.02* 14 +13*0.0028+2*0.025 = 0.366 m

After above calculation properties required for SAP is calculated are listed below.

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Properties for analysis in SAP 2000

U1 Linear Effective Stiffness = 10600000000 N/m

U2 and U3 Linear Effective Stiffness = 1018112.85/m

U2 and U3 Nonlinear Stiffness = 9940970 N/m

U2 and U3 Yield strength = 23858.328N

U2 and U3 Post Yield stiffness ratio 0.095

Damping = 5%.

In SAP2000 an isolator link assigned to each column at the foundation level as a single joint element to connect the superstructure to the ground. Lead rubber Bearing links were applied as link of rubber isolator. The behavior of link elements in SAP2000 is defined in the Link/Support Property. Directional properties U1, U2, U3, R1, R2, and R3 are mechanical behavior in six directions. The properties for axial deformation (U1) is linear only, shear deformations (U2, U3) are linear and nonlinear. And torsional deformation (R) about U1 is linear only. Rotations above U2 and U3 are (R2 & R3) are linear only.

Table 4. Lead Rubber Bearing details

SR.NO	Parameters	G+8
1	Diameter of Bearing	676 mm
2	Thickness of individual rubber layer	20mm
3	Numbers of rubber layer	14
4	Thickness of individual steel plates	2.8mm
5	Numbers of steel plates	13
6	Thickness of top and bottom steel plates	25mm
7	Total height of bearing	366mm
8	Diameter of lead core	60mm

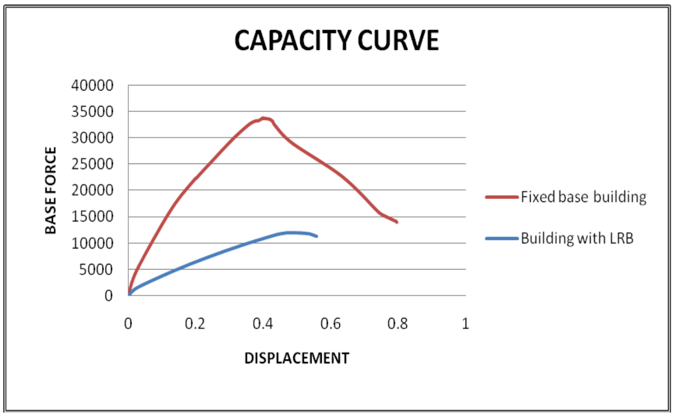
9. RESULT OBTAINED FROM SOFTWARE SAP2000

All results are computed after analysis of model in software SAP2000.

Table 5. Time period

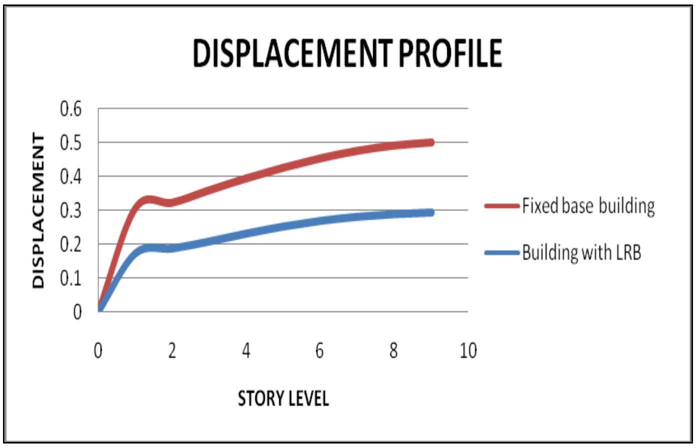
Storey	Fixed base building		Lead rubber isolated building	
G+8	Mode 1	Mode 2	Mode 1	Mode 2
	1.60455	1.01441	4.27183	3.53122

Results obtained from pushover analysis

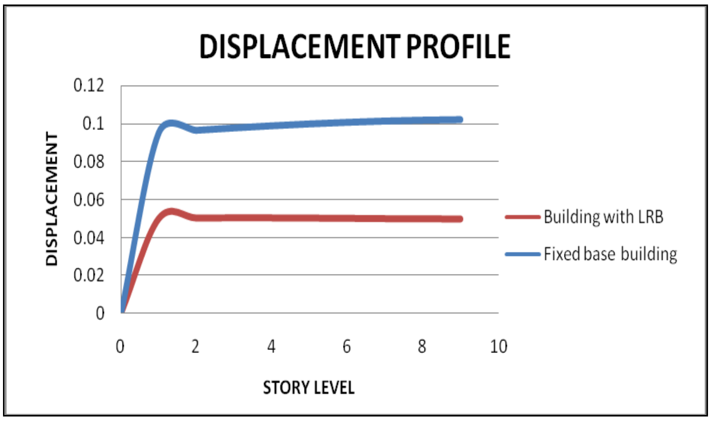


Graph 1: Capacity curve of G+8 storey building with & without LRB

Results obtained from time history analysis

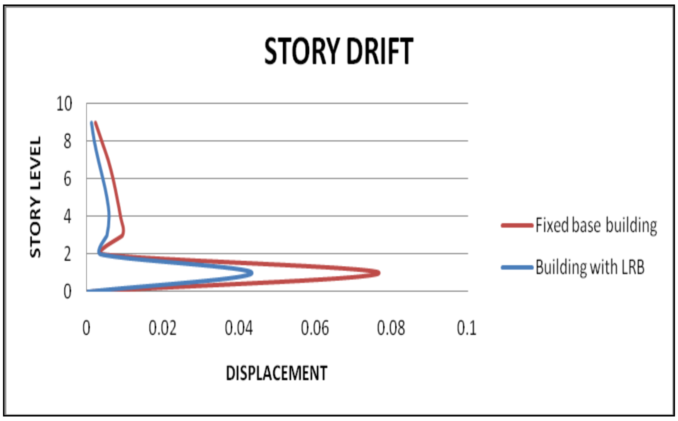


Graph 2: Displacement profile of G+ 8 storey building for Kobe ground motion data

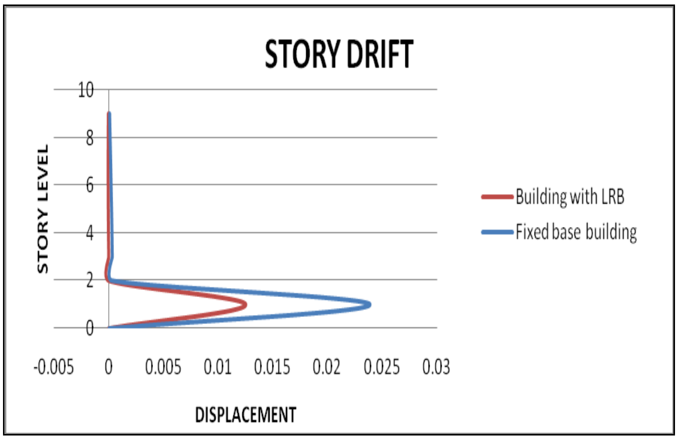


Graph 3: Displacement profile of G+ 8 storey building for superstition ground motion data

Storey drift of structure



Graph 4: Inter Story Drift of G+8 Story with LRB for Kobe Ground motion data.



Graph 4: Inter Story Drift of G+8 Story with LRB for superstition Ground motion data.

10. CONCLUSION

From the comparative study of fixed base and base isolation methods by using lead rubber bearing the following conclusions are made:

1. Time periods are increased which increases reaction time of a structure during earthquake.
2. Base shear reduced after the lead rubber bearing (LRB) is provided as base isolation system which reduces the seismic effect on building.
3. It is observed that when increasing the number of a story maximum storey displacement is becomes considerable.
4. From nonlinear analysis displacement of base isolated building reduced to 25% over the fixed base building. Base shear get reduces 67% and storey drift is get reduces up to 50 - 60%.
5. It can be concluded that the performance of base–isolated structure is efficient in seismic prone areas.

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