

SEISMIC RESPONSE CONTROL OF RC BUILDING BY USING BASE ISOLATION SYSTEM

Sushil P. Lipte¹, Dr. V. R. Rathi², Dr. P. K. Kolase³

¹Post Graduate Student, Civil Engineering Department,
Pravara Rural Engineering College, Loni, Maharashtra, India

²Professor, Civil Engineering Department,
Pravara Rural Engineering College, Loni, Maharashtra, India

³Associate Professor, Civil Engineering Department,
Pravara Rural Engineering College, Loni, Maharashtra, India

ABSTRACT

The software investigation of base isolation compared with fix base, generally while analyzing structure we provide fix support for the foundation over here isolator are used instead of fixed base and compared. These are compared for base shear, story drift, story acceleration, displacement, reaction etc. In this study, a comparison is made of the seismic response of a G+7 & G+14 story base-isolated building by idealizing the superstructure as rigid and flexible. In this work the Lead Rubber Bearing (LRB) isolation system is considered. Two different heights of buildings low and medium rise in zone V is considered. For such analysis ETAB software was used. 3 bay G+7 & G+14 story structure was analyzed for dynamic earthquake using response spectrum method. The results obtained are Story drift, Story acceleration, Base shear, Lateral displacement, Reaction at base. This paper intends to demonstrate how an isolation system can be efficient, evaluating its effectiveness for the building in terms of story acceleration, base shear, story drift and story displacement reductions.

Keywords: Base Isolation, Etabs, Lead Rubber Bearing, RC Building, Response Spectrum Analysis.

1. Introduction

During the last two decades considerable advances have been accomplished in the area of seismic protection of structures, furthermore new promising systems have been developed which can be incorporated in structures to improve their response when excited by earthquakes. These systems, also known as earthquake-protection systems, consisting of passive, active, semi-active or hybrid devices can considerably minimize the seismic demand of buildings and structures. In the latter approach, the horizontal decoupling of the structure achieved through insertion of bearings at foundation level, transfers it in to lower frequency range where the seismic energy acting on the structure is beyond that of resonance and dissipates the energy through damping, the technique is known as base-isolation. 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

motions. In addition, the damping capacities provided by the isolation systems help to dissipate the energy imparted during seismic activities. Thus, the isolation becomes an attractive approach to safeguard the structures against earthquakes without any requirement for modification in the superstructure. The obvious natural extension of these concepts gave birth to a new idea of adding lateral flexibility to the structures at foundation level to accommodate ground motion and float the structure above, almost rigidly, during an earthquake event; the concept named base-isolation.

Seismic base-isolation, which is now recognized as a mature and efficient technology, can be adopted to improve the seismic performance of strategically important buildings such as schools, hospitals, industrial structures, elevated water tanks, multi-storied residential complexes etc. in addition to places where sensitive equipments are intended to protect from the hazardous effects during earthquake. Conventional seismic design attempts to make buildings that do not collapse under strong earthquake shaking, but may sustain damage to non-structural elements and to some structural members in the building. 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. Non-structural components are sensitive to large floor accelerations 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 to innovate earthquake resisting design approach to reduce such type of structural damages there are two basic technologies used to protect buildings from damaging earthquake effects. These are base isolation devices and seismic dampers. The idea behind base isolation is to detach (isolate) the building from the ground in such a way that earthquake motions are not transmitted up through the building or at least greatly reduced.

1.1 Concept of base isolation

The principle of base isolation is typically conceptually explained by using figure 1. (a) and (b) show a structure without and with base isolation, respectively. It is seen that the major difference between (a) and (b) is that in (b), the structure is set on top of isolation several bearings. When the ground moves with acceleration A_g , the superstructure will move accordingly with a displacement Δ , and a reduced level of absolute acceleration, denoted by A_a , rather than the original level A_{a0} .

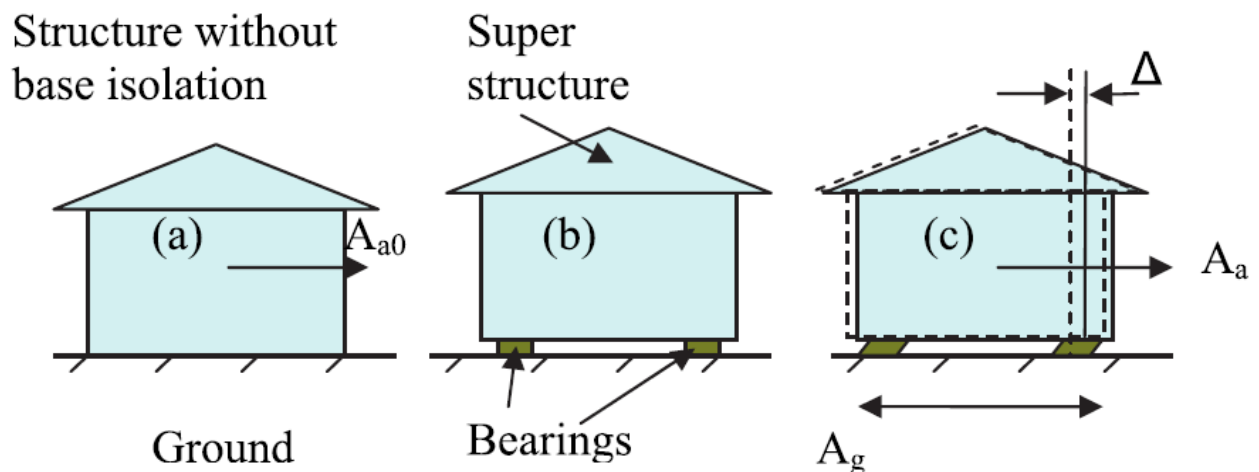


Fig.1: Concept of base isolation

1.2 Base isolation

In the concept of base isolation the building is resting on flexible pads. When the ground shakes, the vibrations are absorbed by the flexible pads and the building above does not move. Thus, no force is transferred to the building due to shaking of the ground; simply, the building does not experience the earthquake. Now, the flexible pads that offers resistance against lateral movements, some effect of the ground shaking will be transferred to the building above. If the flexible pads are properly chosen, the forces induced by ground shaking can be a few times smaller than that experienced by the building built directly on ground, namely a fixed base building.

The flexible pads are called base-isolators, whereas the structures protected by means of these devices are called base isolated buildings. The main feature of the base isolation technology is that it introduces flexibility in the structure. The isolators are often designed to absorb energy. This helps in further reducing the seismic response of the building. A careful study is required to identify the most suitable type of device for a particular building. Also, base isolation is not suitable for all buildings. Most suitable buildings for base-isolation are low to medium-rise buildings rested on hard soil underneath. High-rise buildings or buildings rested on soft soil are not suitable for base isolation.

The structural bearing criteria include vertical and horizontal loads, lateral motion and lateral rotation that transferred from the superstructure into the bearing and from the bearing to the substructure. Bearing allows for stress-free support of the structure in terms of

- (1) They can rotate in all directions,
- (2) They deform in all directions,
- (3) They take horizontal forces (earthquake).

In this study lead rubber bearings are used as the base isolation system.

1.3 Objective

The study of the dynamic characteristics of the base-isolated and fixed base multi story building. To examine the influence of isolator characteristics and compare the seismic response of base-isolated multi story building for zone V.

The work includes design of G+7 and G+14 story reinforced concrete symmetric building in accordance with IS1893:2002 provisions, one with fixed base and other is base isolated. By analyzing the fixed base building, we get maximum reactions under each column. For these maximum values lead rubber bearings (LRBs) are analyzed in order to isolate the superstructure from substructure. 3 bay G+7 and G+14 story structure was analyzed for dynamic earthquake using Response Spectrum Analysis. Modeling and analysis is done using ETAB software. The design is based on IS1893-2002 and IS875-1987.

The specific objectives of the study are:

1. To carry out modeling and analysis of fixed base and isolated base buildings by using E-TABS software and compared their results, to identify the effectiveness of isolation system.
2. To evaluate story displacement in case of multi-story building structures.
3. Characterizing base-isolation structures and the study for the parameters influencing its behavior during earthquake.

4. To carry out comparison between fixed base and base isolated building on the basis of their dynamic properties like reaction, base shear, story drift, translation and rotation at different mode and story acceleration.

1.4 Lead rubber bearing

The Lead (laminated) Rubber Bearing (LRB) base isolation system is the most common system. The basic components are steel and rubber plates built in alternate layers. The dominant feature of LBR system is a parallel action of linear spring and damping. Generally a LBR exhibits high damping capacity, horizontal flexibility and high vertical stiffness. The LRB system is characterized by two parameters: natural frequency and damping constant. The damping constant of the system varies considerably with strain of the bearing.

The main advantages of rubber bearing system are:

1. Effective isolation is achieved. It will decrease the structural response to $1/2 - 1/8$ of the traditional structural response.
2. Stable character of isolators over a long working life.
3. Recovery of the displacement after earthquakes.
4. Vertical tension capacity is good.
5. Isolators are insensitive for foundation settlement, which are generally small in magnitude. It could adjust the structure force by deformation of rubber bearings when foundation settlement of building happens before or after earthquakes.

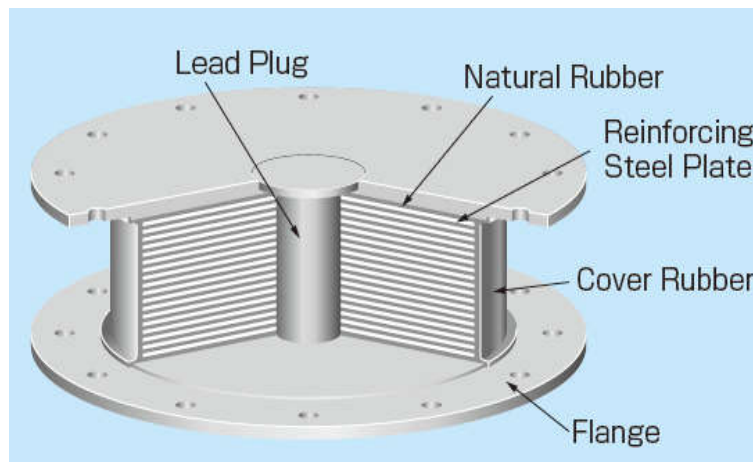


Fig.2: Cross section of LRB

2. Literature Review

Many methods have been proposed for achieving the optimum performance of structures subjected to earthquake excitation. The use of lead rubber bearing isolators for absorbing energy is the best technique. Many papers have been published related with base isolation technique as an earthquake resistant device. Some of them are discussed below.

Sayed-Ahmed (2012) [1]: In this paper the base isolation (BI) system for buildings is introduced to decouple the building structure from potentially damaging induced by earthquake motion, preventing the building superstructures from absorbing the earthquake energy. The study analysis performed to check for the adequacy

of the base isolation against building lateral drift and inter-story drift as per allowance in National Building Code of Canada 2010. The analysis represents a case study for symmetric steel building to show the ultimate capacity of the selected structural bearing, and to make a comparison for the difference between the isolated base and the fixed base buildings. Initial results show that the presence of the structural rubber bearing reduces significantly the vertical displacement, moment and shear generated for the same mode.

Saiful Islam (2012) [2]: This paper reviews a number of articles on base isolation incorporation in building structure. Lead rubber bearing (LRB), high damping rubber bearing (HDRB), friction pendulum system (FPS) have been critically explored. This study also addressed the detail cram on isolation system, properties, characteristics of various device categories, recognition along with its effect on building structures. Meticulous school work has also been accomplished about installation technique for various site stipulations. The entire superstructure is supported on discrete isolators whose dynamic characteristics are chosen to uncouple the ground motion. Displacement and yielding are concentrated at the level of the isolation devices, and the superstructure behaves very much like a rigid body. Rigorous reckoning illustrated the isolation system as very innovative and suitable in buildings to withstand the seismic lateral forces and also contributed to safety ensuring flexibility of structures.

Somwanshi et al (2015) [3]: This paper deals with a new type of base isolation application. The work includes design of 13-story reinforced concrete symmetric and Asymmetrical building in accordance with IS 1893:2002 provisions. Modeling and analysis is done using E-TABS software for Bhuj earthquake ground motion records. Maximum vertical reaction is obtained from analysis in E-TABS software. This paper intends to demonstrate how an isolation system can be efficient, evaluating its effectiveness for the building in terms of maximum shear force, maximum bending moment, base shear, story drift and story displacement reductions.

Darshale et al (2016) [4]: This study is concerned with the effects of various vertical irregularities on the seismic response of a structure and controls this response using base isolation. The objective of the study is to carry out response spectrum analysis and time history analysis of fixed base and base isolated vertically irregular RCC structure according to IS 1893:2002 (Part-1). Three types of vertical irregularities namely mass irregularity, stiffness irregularity and vertical geometry irregularity were considered for modal analysis of G+14 regular RCC structure. Base isolation reduces the lateral displacement, shear forces, bending moments, base shear, story acceleration, inter story drift as compared to the conventional fixed base structure. Which shows the effectiveness of base isolation and concluded that base isolation is very effective seismic response control device.

Devi et al (2016) [5]: This paper presents a response spectrum analysis performed on two plan irregular rcc building with re-entrant corners using the software ETABS 2015. The main objective here is to study the seismic response control on a structure by providing isolators and comparing between the fixed based and isolated base building. The paper investigates the effectiveness of the rubber isolator against friction pendulum system for various plan irregular building. This paper studies various parameters such as total base shear force, story acceleration, displacement and time period of a building with respect to the fixed base and isolated base.

3. Methodology

The RC buildings are subjected to dynamic load of earthquake. Analysis of seismic isolation system was analyzed by response spectrum method. However the building subjected to dynamic load. The response spectrum method can also be applied for lateral load analysis, hence 3 D analysis is carried out using ETAB software. Firstly RC building analyzed for the first case fixed base then for second case analyzed by providing instead of fixed base rubber base isolator are placed in between the superstructure and substructure. Then compare their results to check the effectiveness of isolator.

In accordance with these design aims, the following aims should be undertaken:

1. Compute the dimensions of the isolators that will result in the desired period shift for reducing the earthquake forces
2. Determine the damping ratio of the isolator such that the displacement of the structure can be controlled within the design limit.
3. Assigning properties of bearings and different element of building for earthquake zone V.
4. Comparing results for earthquake zone V for fixed base and base isolated RC buildings.

3.1 Modelling of structure

3.1.1 Description of building (Model-I)

Structural model of fixed base and base isolated buildings are analyzed for G+7 story. The modeling of base isolated and fixed base building and seismic analysis by response spectrum analysis is carried by using Etabs software using IS1893:2002, IS875:1987 and IS456:2000 code. The following data is used for analysis.

Considered two cases fixed base and isolated base.

- Total No. of floors: 8
- Plan Dimensions: 12 m X 12 m
- No. of bays: X direction – 3 Nos., Y direction – 3 Nos.
- Size of bays: X direction – 4m, Y direction – 4m.
- Height of floor: 3.0m
- Parapet height -1.0m
- No. of Column: 16
- Size of Column: From ground to story five-0.5m x 0.5m,
Story five to story eight-0.45m x 0.45m.
- Size of Beams: 0.23m X 0.45m.
- Size of slabs: Two way slab with thickness 0.125m
- Concrete Mix design: M - 25
- Zone of Location: Zone V
- Zone Factor: 0.36.

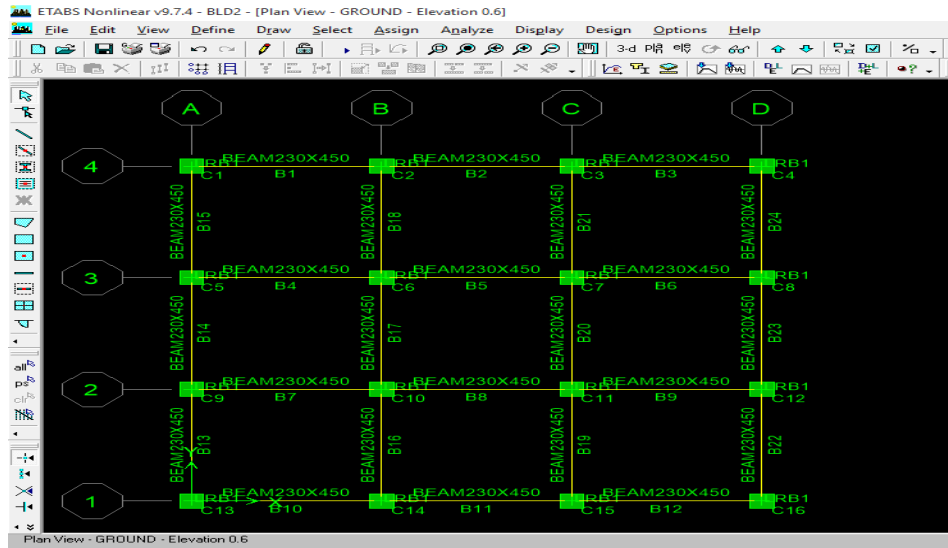


Fig.3: Framing plan for model-I

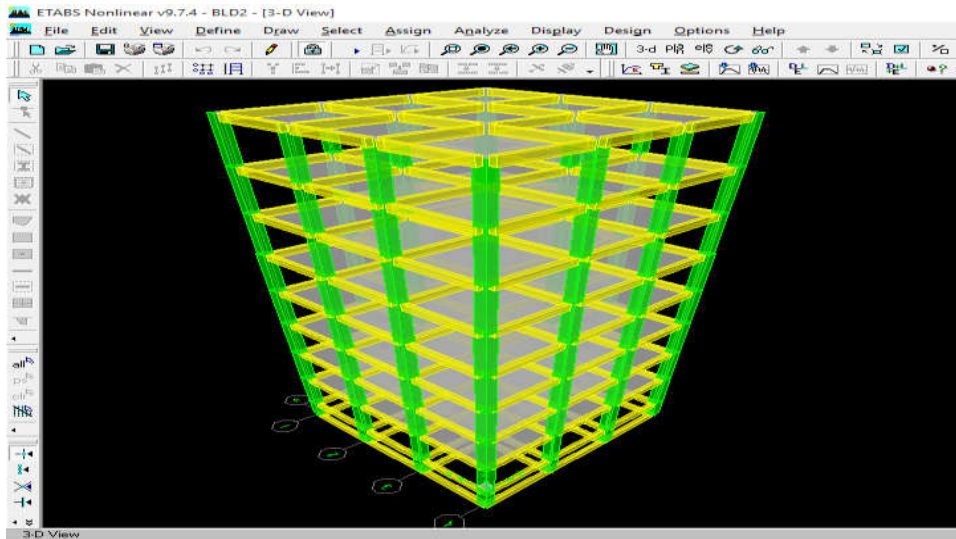


Fig.4: 3D view of model-I

3.1.2 Description of building (Model-II)

Structural model of fixed base and base isolated buildings are analyzed for G+14 story. The modeling of base isolated and fixed base building and seismic analysis by response spectrum analysis is carried by using Etabs software using IS1893:2002, IS875:1987 and IS456:2000 code. The following data is used for analysis.

Considered two cases fixed base and isolated base.

- Total No. of floors: 15
- Plan Dimensions: 12 m X 12 m
- No. of bays: X direction – 3 Nos., Y direction – 3 Nos.
- Size of bays: X direction – 4m, Y direction – 4m.
- Height of floor: 3.0m

- Parapet height -1.0m
- No. of Column: 16
- Size of Column: From ground to story seven-0.6m x 0.6m,
 Story seven to story eleventh-0.55m x 0.55m,
 Story eleven to story fifteen-0.5m x 0.5m.
- Size of Beams: 0.23m X 0.45m.
- Size of slabs: Two way slab with thickness 0.125m
- Concrete Mix design: M - 25
- Zone of Location: Zone V
- Zone Factor: 0.36.

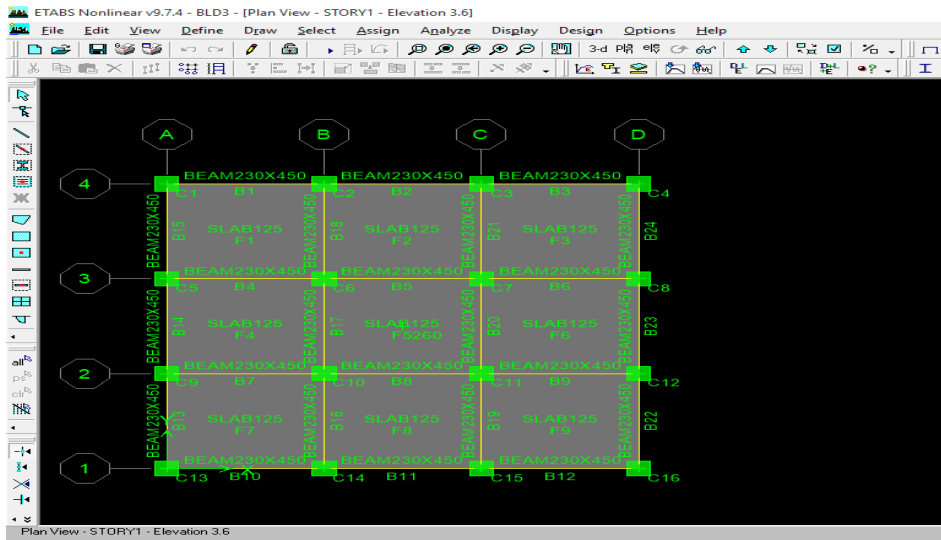


Fig.5: Framing plan for model-II

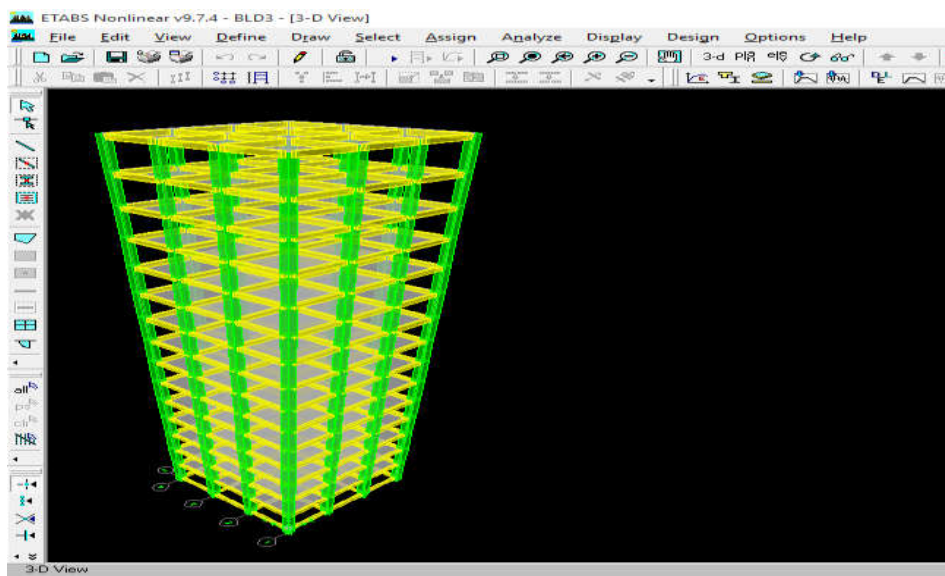


Fig.6: 3D view of model-II

3.2 Load consideration

- Live load= 2.0 kN/m²
- Floor finish= 1.5 kN/m²
- Wall load= $0.23 \times 18.5 + 0.03 \times 22 = 4.915 = 5 \text{ kN/m}^2$ (Inclusive plaster).
= $(3-0.45) \times 5 = 12.75 \text{ kN/m}$.

3.3 Dynamic consideration

For response spectrum cases

Table 1: Dynamic consideration

	X-direction	Y-Direction
Damping	0.05	0.05
Modal combination	CQC	CQC
Directional combination	SRSS	SRSS
u1 and u2 (trial)	U1=1.0	U2=1.0

Note: CQC – Complete Quadratic Combination.

SRSS – Square Root of Sum of Squares.

3.4 Properties of lead rubber bearing isolator

Table 2: Properties of LRB for G+7 building

U1 Linear Effective Stiffness	100961.54 kN/m
U2 and U3 Linear Effective Stiffness	218.75 kN/m
U2 and U3 Nonlinear Stiffness	674.07 kN/m
U2 and U3 Yield Strength	16.85 kN
U2 and U3 Post Yield Stiffness Ratio	0.1
U1 PYSR	0.1

Table 3: Properties of LRB for G+14 building

U1 Linear Effective Stiffness	355111.95 kN/m
U2 and U3 Linear Effective Stiffness	325.52 kN/m
U2 and U3 Nonlinear Stiffness	1307.9 kN/m
U2 and U3 Yield Strength	32.7 kN
U2 and U3 Post Yield Stiffness Ratio	0.1
U1 PYSR	0.1

3.5 Dimensions of lead rubber bearing isolator

Table 4: Dimensions of LRB for G+7 building

Sr. No.	Particular	LRB For Zone V
1.	Diameter of the bearing	235.5 mm
2.	Diameter of lead core	44.2 mm
3.	Total height of bearing/depth	192 mm
4.	Numbers of rubber layer	12 nos
5.	Thickness of individual rubber layer	10 mm
6.	Numbers of steel plates	11 nos
7.	Thickness of individual plates	2 mm
8.	Thickness of bottom and top plates	25 mm

Table 5: Dimensions of LRB for G+14 building

Sr. No.	Particular	LRB For Zone V
1.	Diameter of the bearing	353 mm
2.	Diameter of lead core	57.3 mm
3.	Total height of bearing/depth	337 mm
4.	Numbers of rubber layer	20 nos
5.	Thickness of individual rubber layer	10 mm
6.	Numbers of steel plates	19 nos
7.	Thickness of individual plates	3 mm
8.	Thickness of bottom and top plates	40 mm

4. Result And Discussion

4.1 Maximum point displacement (story displacement)

Maximum point displacement value for each story is considered and it is maximum at top story. It is to be compared with fixed base and base isolated buildings for both G+7 and G+14 story building and as shown in figure 7&8 and 8&9 respectively. From figure, it is observed that the point displacement values are significantly reduced for base isolated building for both G+7 and G+14 story building as compared to fixed base building. The point displacement values are maximum at top story and hence we consider for top story for comparison from figure 8&10 for, it is to be observed that the percentage decrease in displacement for low rise building is 14.59% and for mid rise building is 15.05%.

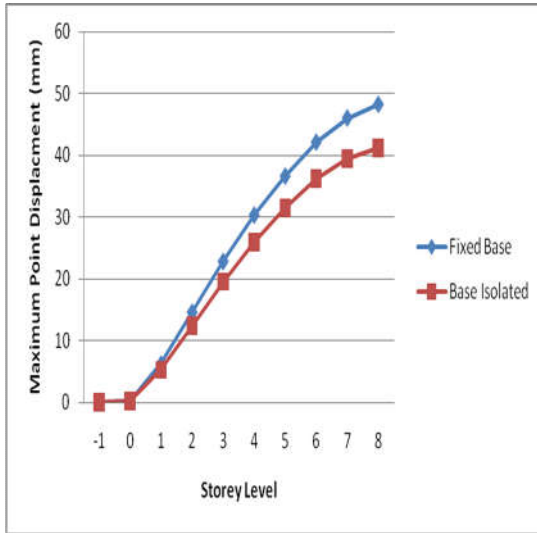


Fig.7: Maximum point displacement in G+7 story building at each story.

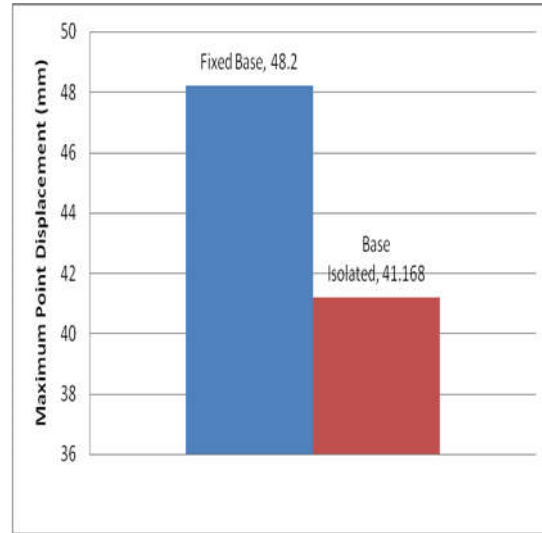


Fig.8: Maximum point displacement in G+7 story building at top story.

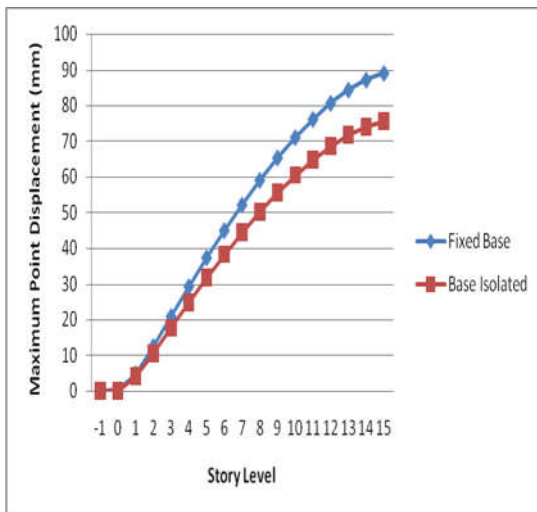


Fig.9: Maximum point displacement in G+14 story building at each story.

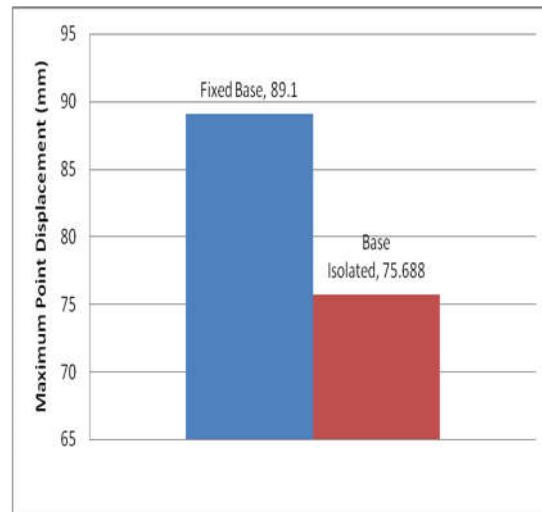


Fig.10: Maximum point displacement in G+14 story building at top story.

4.2 Maximum shear force and base shear

Maximum value for shear force in building is considered and also the values are consider at base for base shear. It is to be compared with fixed base and base isolated buildings for both G+7 and G+14 story building and as shown in figure 11&12 and 13&14 respectively. From figure, it is observed that the base shear values are less for base isolated building for both G+7 and G+14 story building as compared to fixed base building. Also the percentage decrease in base shear at base for low rise is 15.71% and for mid rise is 16.03%.

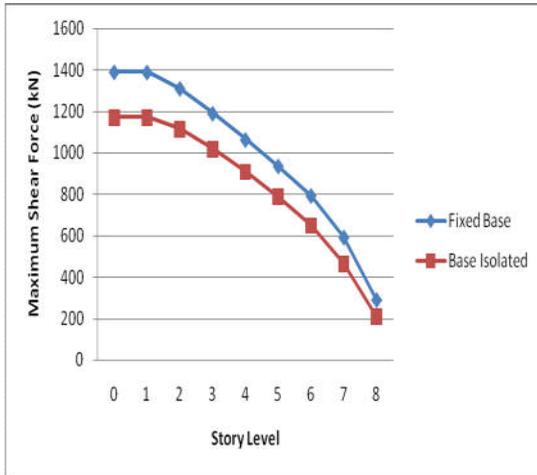


Fig.11: Maximum shear force in G+7 story building at each story.

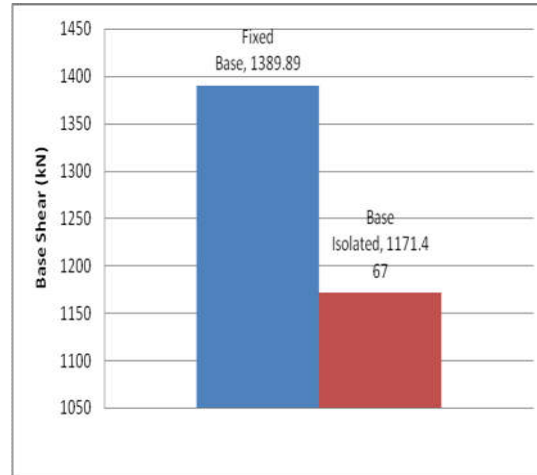


Fig.12: Maximum base shear in G+7 story building at base.

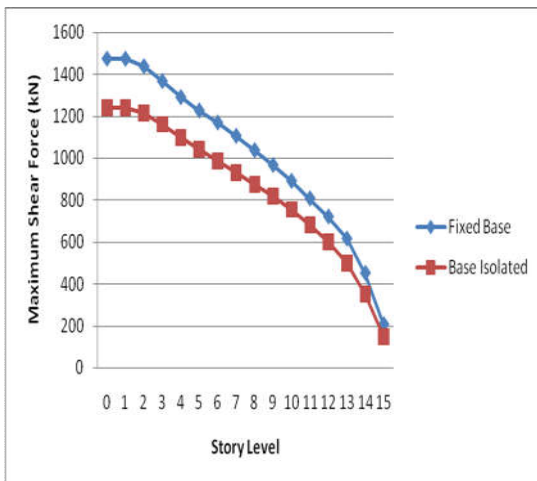


Fig.13: Maximum shear force in G+14 story building at each story.

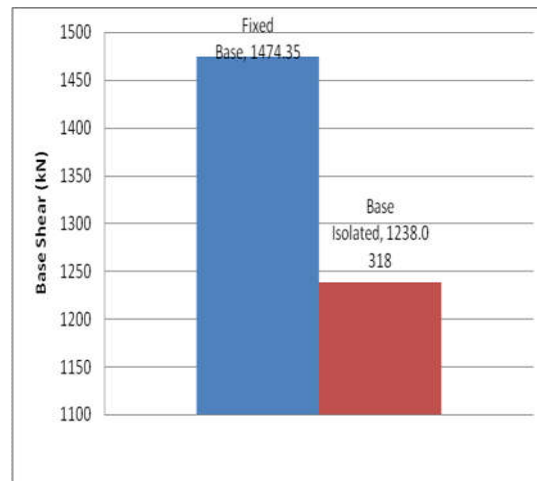


Fig.14: Maximum base shear in G+14 story building at base.

4.3 Story acceleration

The story acceleration Vs story level graph of fixed base and base isolated G+7 and G+14 story building with X and Y directions are as shown in figure 15&16 respectively. From figure, it is observed that story acceleration in base isolated building is more as compared with the fixed base but the difference in the percentage increase in story acceleration of base isolated building is very less hence there is not that much change in story acceleration.

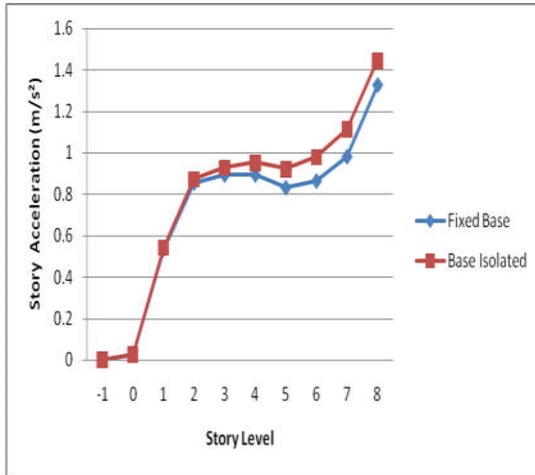


Fig.15: Story acceleration in G+7 story building.

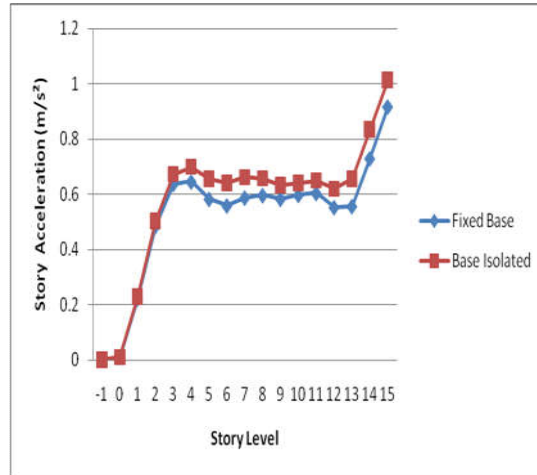


Fig.16: Story acceleration in G+14 story building.

4.4 Story drift

The story drift Vs story level graph of fixed base and base isolated G+7 and G+14 story building with X and Y directions are as shown in figure 17&18 respectively. From figure, it is observed that the values of story drift for both base isolated building and fixed base building in both cases are near about same at base and at top story but main difference is observed in the middle stories where the maximum story drift is to be observed and it is to be observed that the base isolated building both G+7 & G+14 story building have significantly less values as compared to fixed base.

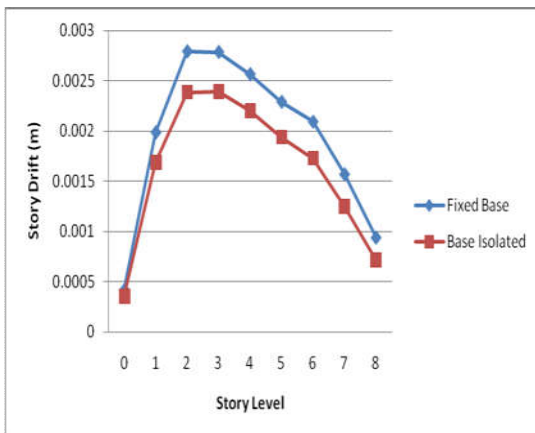


Fig.17: Story drift in G+7 story building.

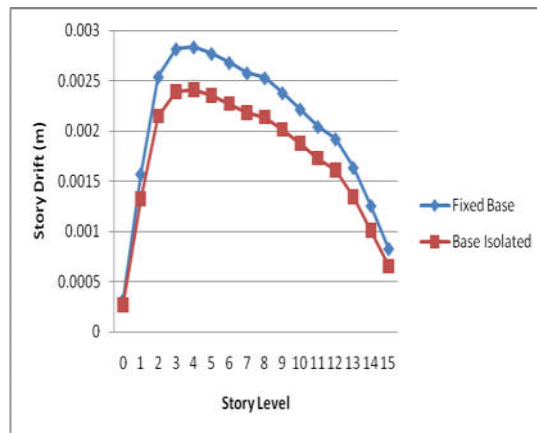


Fig.18: Story drift in G+14 story building.

5. Conclusion

1. From analysis results, it is observed that base isolation decouples the building from sub structure to super structure and resist against earthquake induced load.
2. The base isolators were found to be an excellent seismic control device for these low-rise (G+7) and mid-rise (G+14) buildings in controlling forced responses such as shear force, base shear, story drift, story acceleration and story displacement.

3. It is observed that fixed base building have higher values for story displacement at top of building whereas the base isolated building has lower value of story displacements at top of the building for both low-rise and mid-rise buildings. However, it has been observed that the point displacements increases drastically as the floor height increases in fixed base building in contrast to that in the base isolated buildings have less values.
4. It is observed that fixed base building have higher values for base shear at base of building whereas the base isolated building has lower value of base shear at base of the building for both low-rise and mid-rise buildings. Also it is observed that the shear force is significantly reduced in base isolated building as compared to fixed base building.
5. It is observed that fixed base building have lower values for story acceleration whereas the base isolated building has higher value of story acceleration for both low-rise and mid-rise buildings but it is to be observed that the percentage increase in story acceleration of base isolated building is very less hence it is to be consider that due to isolator there is not that much change in story acceleration as compared to fixed base. Hence we can say that, there is no impact on the story acceleration of a building by using base isolator.
6. It is observed that fixed base building have significant higher values for story drift at middle story whereas the base isolated building has lower value of story drift at middle story for both low-rise and mid-rise buildings. However, it is to be observed that the story drift have less values at base and top story and also the maximum story drift is to be observed in the mid story for both low-rise and mid-rise buildings.
7. From all above discussion it is to be observed that base isolation system is not suitable for small project.
8. From analysis results, it is to be observed that base isolation reduces the seismic response in comparison to the fixed base building and control the damages in building during strong ground shaking.
9. From the comparison between the base isolated and fixed base building, it is to be observed that the shear force, base shear, story drift, story displacement decreases as compared to fixed base building and the story acceleration of base isolated building is increase in some amount.

References

Journal papers:

- [1] Mahmoud Sayed-Ahmed, "Building with base isolation techniques" *Al-Azhar University Engineering Journal, JAUES, Vol. 7, No. 1, Dec. 2012.*
- [2] A. B. M. Saiful Islam, "Seismic isolation in buildings to be a practical reality: Behavior of structure and installation technique", *Journal of engineering and technology research Vol. 3(4), pp. 99-117, April 2011.*
- [3] Ms. Minal Ashok Somwanshi and Mrs. Rina N. Pantawane, "Seismic analysis of fixed based and base isolated building structures", *International journal of multidisciplinary and current research, Vol.3 (July/Aug 2015).*
- [4] S. D. Darshale, N. L. Shelke, "Seismic response control of vertically irregular r.c.c. structure using base isolation", *International journal of engineering research, Volume No.5 Issue: Special 2, pp: 683-689, 27-28 Feb. 2016.*
- [5] Devi Sreenivas, Ancy Mathew, "Seismic performance of base isolated buildings with plan irregularity", *IJSTE - International Journal of Science Technology & Engineering, Volume 3, Issue 02, August 2016.*

- [6] Donato Cancellara, Fabio De Angelis, "Assessment and dynamic nonlinear analysis of different base isolation systems for a multi-story RC building irregular in plan" *Department of Structures for Engineering and Architecture, University of Naples Federico II, Naples, Italy, Accepted 22 February 2016.*
- [7] Meena Noorzai, M.N Bajad, Neha Dodal, "Evaluation of Fixed Base vs. Base Isolated Building Systems" *International Journal of Engineering Research and Development, Volume 11, Issue 05 (May 2015), PP.33-42.*
- [8] Akil Ahmed, "Background Study of Base Isolated Structure and Analysis of Base Isolated Frame", *International Conference on Inter Disciplinary Research in Engineering and Technology 2016, ISBN 978-81-929866-0-9 [ICIDRET 2016].*
- [9] Vasant A. Matsagar, R.S. Jangid, "Influence of isolator characteristics on the response of base-isolated structures" *Department of Civil Engineering, Indian Institute of Technology Bombay, Powai, Mumbai, India, Engineering Structures 26 (2004) 1735–1749.*
- [10] Vojko Kilar, David Koren, "Seismic behaviour of asymmetric base isolated structures with various distributions of isolators" *University of Ljubljana, Faculty of Architecture, Zoisova 12, SI-1000 Ljubljana, Slovenia, Accepted 1 December 2008.*
- [11] C.P. Providakis, "Effect of LRB isolators and supplemental viscous dampers on seismic isolated buildings under near-fault excitations" *Applied Mechanics Lab, Department of Applied Sciences, Technical University of Crete, GR-73100 Chania, Greece, accepted 13 July 2007.*
- [12] Nikita Gupta, Dipali sharma, Poonam, "State Of Art Review-Base Isolation for Structures" *International Journal of Scientific & Engineering Research, Volume 5, Issue 5, May-2014.*
- [13] Yogesh Narayan Sonawane, Mahesh Navnath Patil, "Base Isolation for Multistoried Buildings with Lead Rubber bearing" *International Journal of New Innovations in Engineering and Technology, ISSN : 2319-6319, Volume 4 Issue 4 – April 2016.*
- [14] Radmila B. Salic, Mihail A. Garevski and Zoran V. Milutinovic, "RESPONSE OF LEAD-RUBBER BEARING ISOLATED STRUCTURE", *The 14th World Conference on Earthquake Engineering, Beijing, China, October 12-17, 2008.*

Codes:

- [15] IS 1893, *Indian Standard Code of Practice for Criteria for Earthquake Resistant Design of Structures*, Part 1, General Provisions and Buildings, Bureau of Indian Standards, New Delhi, 2002.
- [16] IS 456, *Indian Standard for Plain and Reinforced Concrete - Code of Practice*, Bureau of Indian Standards, New Delhi, 2000.
- [17] IS 875 part I&II, *Code of practice for design loads (other than earthquake) for buildings and structures*, Bureau of Indian Standard, New Delhi, 1987.