Seismic Response Reduction of Building Using Base Isolation

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***Abstract*: The different types of vibration-control measures like passive, active, semi-active and hybrid vibration control methods have been developed. Base isolation is a passive vibration control system. The isolator partially reflects and partially absorbs input seismic energy before it gets transmitted to the superstructure. L.R.B isolators are placed between the superstructure and foundation, which reduces the horizontal stiffness of the system. Three types of vertical irregularities namely mass irregularity, stiffness irregularity and vertical geometrical irregularity were considered. Modal analysis of G+14 regular R.C.C structure. Base isolation reduces the lateral displacement, shear forces, bending moments, base shear, storey acceleration, interstorey drift as compared to the conventional fixed base structure. This shows the effectiveness of base isolation and concluded that base isolation is very effective seismic response control device.**

***Keywords*: Base isolation, Fixed base, Vertical irregularities, Response spectrum analysis, Time history analysis, ETABS v 17.0.1.**

I. INTRODUCTION

Seismic Response Control

There are two basic technologies used to protect buildings from damaging earthquake effects. These are base isolation devices and seismic dampers. Many vibration-control measures like passive, active, semi-active and hybrid vibration control methods have been developed. Base isolation is a passive vibration control system. The isolator partially reflects and partially absorbs input seismic energy before it gets transmitted to the superstructure. 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. Seismic dampers are special devices introduced in the building to absorb the energy provided by the ground motion to the building.

Objectives

The objectives of this work are as follows:

1. To carry out modelling and response spectrum analysis of vertically irregular fixed base and base isolated RCC Structure by analytically and comparing with ETABS v 17.0.1 software analysis.
2. Study the effects of earthquake ground motions on these models.
3. To design and study the effectiveness of lead rubber bearing used as base isolation system.
4. To carry out comparison between fixed base and base isolated building on the basis of their dynamic properties like maximum shear force, maximum bending moment, base shear, storey drift, storey displacement and storey acceleration, Time period etc.

II. MATERIALS AND METHODS

Preliminary Data Required for Analysis of R.C.C Structure

The main aim of this project work is to study the dynamic behavior of fixed base and base isolated R.C.C structures, during strong earthquake ground motions. For this fixed base regular building is modeled and analyzed under 1940 El Centro earthquake California ground motion records using ETABS v17.0.1. The Fig. 1 and Fig. 2 shows Grid-Plan of regular R.C.C building and elevation of building respectively. The types of structure considering for analysis and modeling are as follows:

1. Regular Structure
2. Stiffness Irregular Structure
3. Mass Irregular Structure
4. Vertical Geometric Irregular Structure

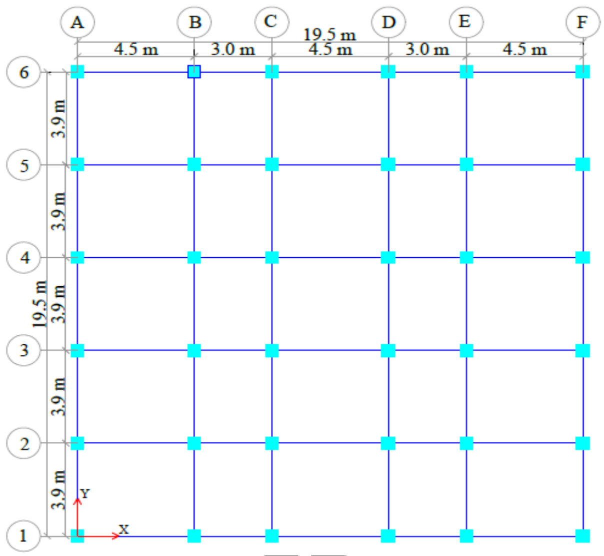

Fig. 1. Grid-plan of regular building model

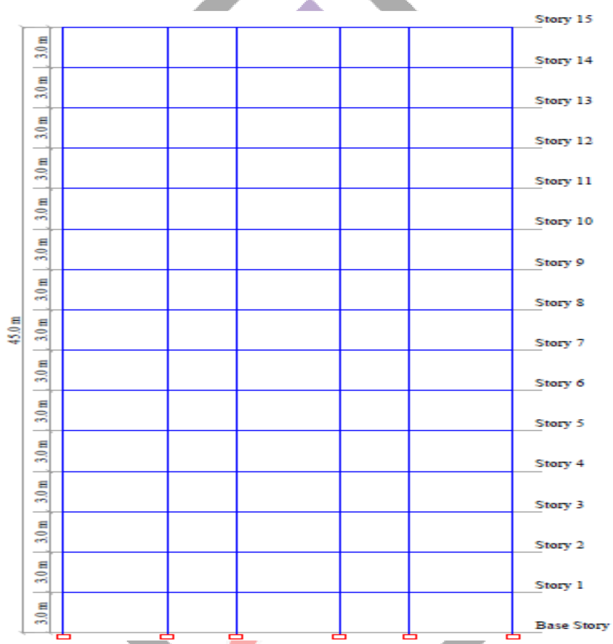

Fig.2. Elevation of regular building model

Table 1. Preliminary data required for analysis of R.C.C structure

Sr. No.	Parameter	Values
1.	Type of structure	Special RC moment resisting frame
2.	Number of storey	G+14
3.	Floor height	3.0 m and 4.5m at 5^{th} story for stiffness irregular structure.
4.	Infill wall	150 mm thick
5.	Materials	Concrete M25 and Reinforcement Fe 500
6.	Frame size	19.5m X 19.5m building size and 12.0m X 19.5m above 10^{th} floor for vertical geometric irregular structure
7.	Grid spacing	4.5m and 3.0m alternative grids in X-direction and 3.9m grids in Y-direction.
8.	Size of column	500 mm x 500 mm; 36no's.
9.	Size of beam	300mm x 600 mm
10.	Depth of slab	165mm

Table 2. Loading according to IS 875-2015 for R.C.C structure

Sr. No.	Parameter	Values
1.	Impose load	3 kN/m^2 and 1 kN/m^2 for Terrace
2.	Floor finish load	1 kN/m^2
3.	Super dead load	1 kN/m^2 and 20 kN/m^2 at 10th storey for mass irregular structure
4.	Specific weight of R.C.C	25 kN/m^3
5.	Specific weight of infill	20 kN/m^3

Table 3. Seismic data required for analysis

Sr. No.	Parameter	Values as per IS 1893:2016 (Part1)	Reference
1.	Type of structure	Special RC moment resisting frame	Table 9, Clause 7.2.6
2.	Seismic zone	V	Table 3, Clause 6.4.2
3.	Zone factor (Z)	0.36	Table 2, Clause 6.4.2
4.	Type of soil	Rock or Hard Soil	Clause 6.4.2.1
5.	Damping	5 %	Clause 7.2.4
6.	Response spectra	As per IS 1893 (part 1):2016	Figure 2, Clause 6.4.6
7.	Time history	El Centro earthquake records	
8.	Load combinations	1) 1.5(DL + IL) 2) 1.2(DL+IL+ EL) 3) 1.5(DL + EL) 4) 0.9DL + 1.5 EL	Clause 6.3.1
9.	Response reduction factor (R)	5	Table 9, Clause 7.2.6
10.	Importance factor (I)	1.5 (Hospital, Schools, Hotel Buildings)	Table 8, Clause 7.2.3

III. RESULTS AND DISCUSSION

Design of Lead Rubber Bearing

A variety of isolation devices including elastomeric bearings (with and without lead core), frictional/sliding bearings and roller bearings have been developed and used practically for a seismic design of buildings during the last 25 years. Among the various base isolation systems, the lead rubber bearings had been used extensively. It consists of alternate layers of rubber and steel plates with one or more lead plugs that are inserted into the holes. The lead core deforms in shear providing the bilinear response (i.e. adds hysteretic damping in the isolated structure) and also provides the initial rigidity against minor earthquakes and strong winds. The steel plates in the elastomeric bearing gives large plastic deformations.

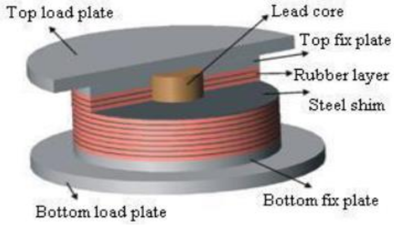

Fig 3. Section of lead rubber bearing

Table 4. Calculation of lead rubber design

Sr. No.	L.R.B Parameter	Horizontal stiffness (K_h) kN/m	Vertical Stiffness (K_v) kN/m
1.	Regular Building	736.14	406242.18
2.	Stiffness Irregular Building	735.63	406642.92
3.	Mass irregular Building	811.31	482153.64
4.	Vertical Geometrical Irregular Building	705.93	376750.99

Maximum Shear Force

Maximum shear force in column of fixed base and base isolated building are shown in Fig.4.it is observed that maximum shear force in base isolated buildings is decreased for regular building by 18.09%, for stiffness irregular building by 22.91%, for mass irregular building 6.49% and for vertical geometrical irregular building by 43.75% in comparison to fixed base building model.

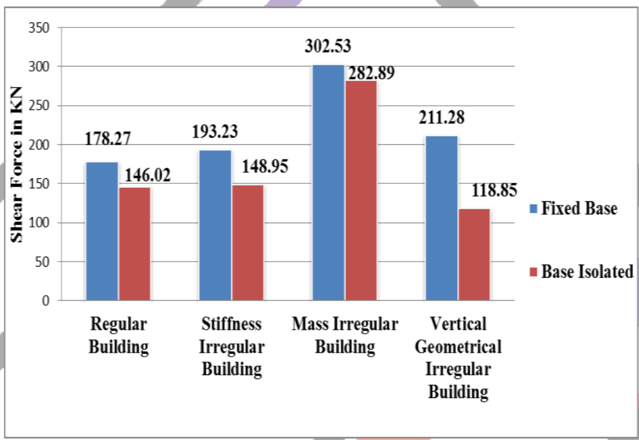

Fig. 4 Maximum shear force in RCC building

Maximum Bending Moment

Maximum bending moment of fixed base and base isolated building are shown in Fig. 5.it is observed that maximum bending moment in base isolated buildings is decreased for regular building by 31.25%, for stiffness irregular building by 32.19%, for mass irregular building 17.80% and for vertical geometrical irregular building by 50.71% in comparison to fixed base building model.

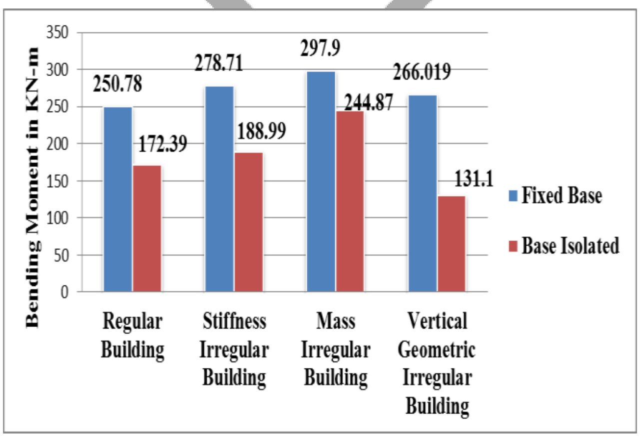

Fig. 5 Maximum bending moment in RCC building

Base Shear

Base shear is estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of the structure. It has been observed that base isolation process is very effective in reducing the base shear as compared to conventional fixed base structure. Maximum base shear of fixed base and base isolated building are shown in Fig. 6. From Fig. 6, it is observed that maximum base shear in base isolated buildings is decreased for regular building by 56.16%, for stiffness irregular building by 47.47%, for mass irregular building 53.59% and for vertical geometrical irregular building by 59.85% in comparison to fixed base building model.

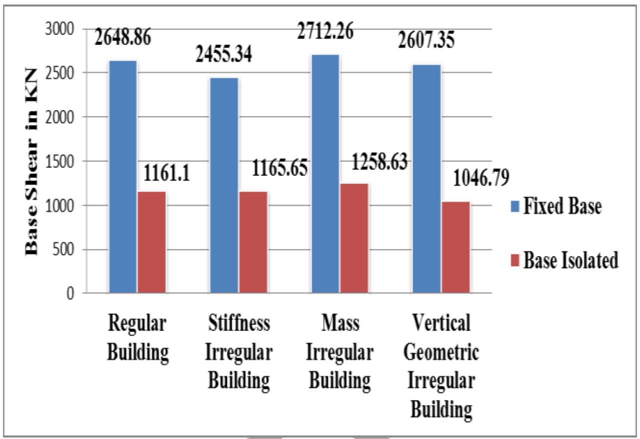

Fig. 6 Maximum base shear in RCC building

Storey Acceleration

Maximum storey acceleration of fixed base and base isolated building are shown in Fig. 7 and Fig. 8. From Fig. 7 it is observed that, storey acceleration is higher at the lower floors and it decreases drastically as we move to the top floors. Also, the storey response of base isolated building decreases and behave linearly as compared to fixed base building. From Fig. 8, it is observed that maximum storey acceleration in base isolated buildings is decreased for regular building by 53.73%, for stiffness irregular building by 52.80%, for mass irregular building 53.73% and for vertical geometrical irregular building by 55.42% in comparison to fixed base building model.

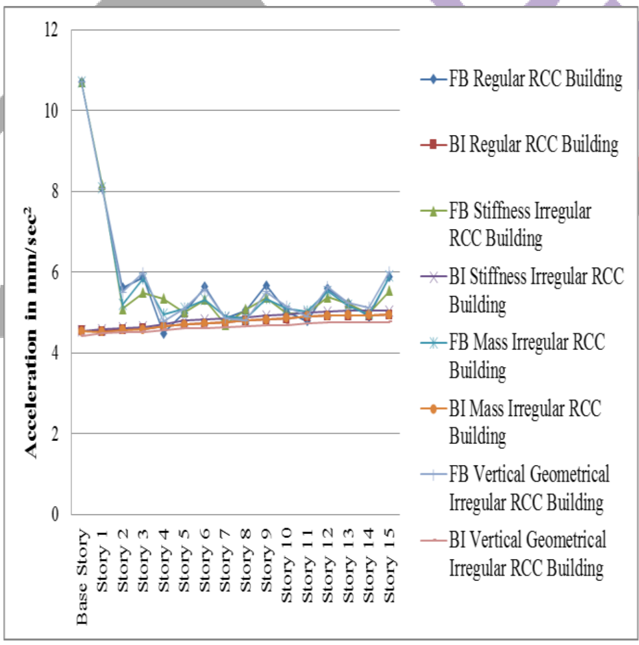

Fig. 7 Storey acceleration in RCC building

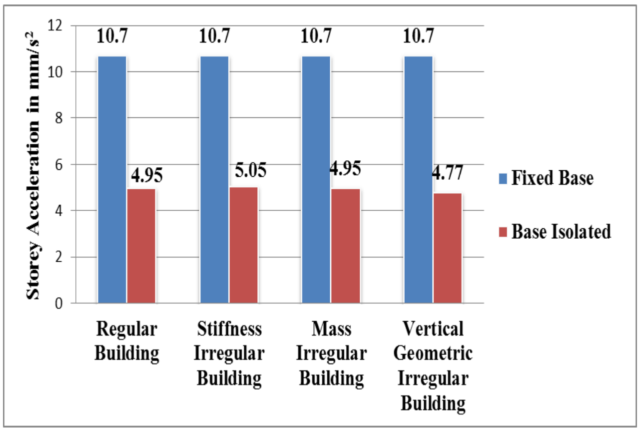

Fig. 8 Maximum storey acceleration in RCC building

Storey Drift

Maximum storey drifts of fixed base and base isolated building are shown in Fig. 9 and Fig. 10. From Fig. 9 it is observed that, for regular building, storey drift is higher at the lower floors and it decreases drastically as we move to the top floors. For stiffness irregular building drift increases at the floor having stiffness irregularity, for mass irregular structure it decreases at mass irregular floor and for vertical geometrical irregular building drift decreases at step of irregularity and then increases. From Fig. 10, it is observed that maximum storey drift in base isolated buildings is decreased for regular building by 50.27%, for stiffness irregular building by 48.34%, for mass irregular building 48.34% and for vertical geometrical irregular building by 54.39% in comparison to fixed base building model.

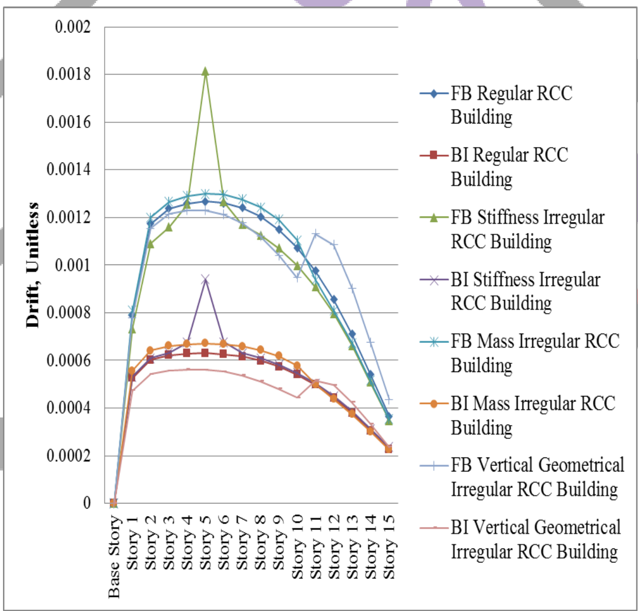

Fig. 9 Storey drift in RCC building

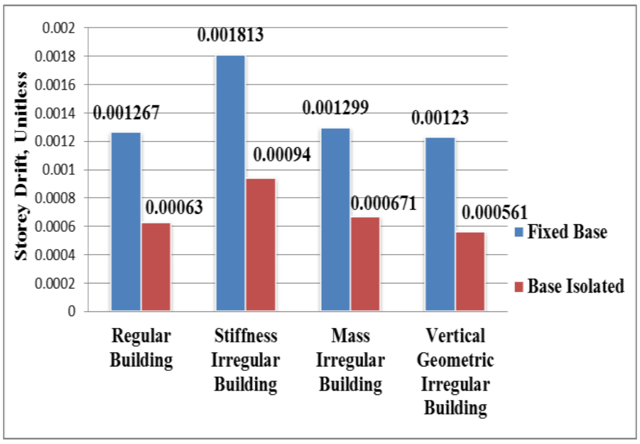

Fig. 10 Maximum storey drift in RCC building

Lateral Displacement

Maximum storey displacement of fixed base and base isolated building are shown in Fig. 11 and Fig. 12. From Fig. 11 it is observed that the displacement in fixed base structure is zero at the base and increases as the storey height increases. Whereas in isolated structures there is a small displacement at the base and increases gradually with the height. From Fig. 12, it is observed that maximum storey displacement in base isolated buildings is increases for regular building by 32.68%, for stiffness irregular building by 32.67%, for mass irregular building 32.24% and for vertical geometrical irregular building by 26.98% in comparison to fixed base building model.

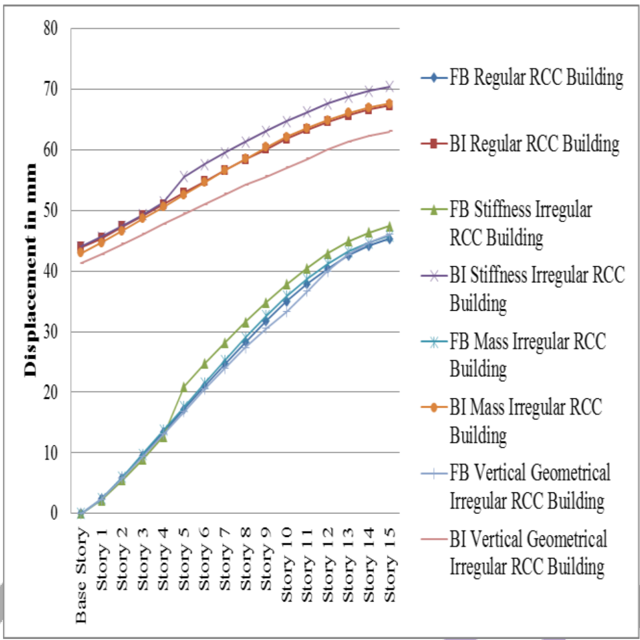

Fig. 11 Lateral displacement in RCC building

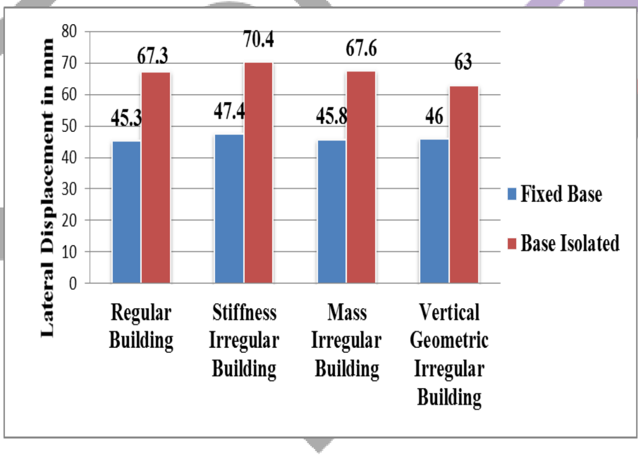

Fig. 12 Maximum lateral displacement in RCC building

First Time Period

Base isolation shifts the fundamental time period of the structure from the dominant period of the earthquake. Generally, it shifts the time period of the structure more than 2 seconds. The dominant periods of the earthquake are in 0.2 to 0.6 second range. The severe acceleration of an earthquake is avoided due to period shift provided by isolation. First time period of fixed base and base isolated building are shown in Fig. 13. From Fig. 13 it is observed that first time period in base isolated buildings is increases for regular building by 57.10%, for stiffness irregular building by 54.27%, for mass irregular building 54.64% and for vertical geometrical irregular building by 59.18% in comparison to fixed base building model.

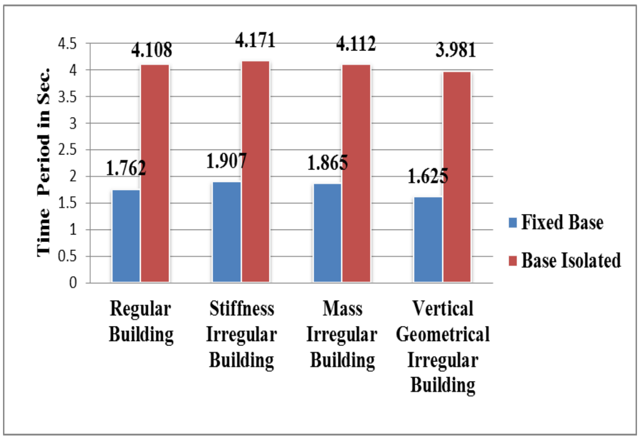

Fig. 13 First time period in RCC building

CONCLUSION

1. The results show that the Base Isolation reduces the shear force by average 20-25% and bending moment by average 30-35% as compared to the conventional fixed base structure.
2. Base Isolation reduces the base shear by 44-62% and reduces the acceleration response by 44-57%.
3. Base Isolation reduces interstorey drift by 44-56% as compared to the conventional fixed base structure.
4. Base Isolation increases the lateral displacement at base story by 24-36% as compared to the conventional fixed base structure.
5. Also, Base Isolation reduces the stiffness and thereby increases the fundamental time period of the building by 51-62% to bring it out of the maximum spectral response region.
6. Therefore, it can be concluded from the results presented here that base isolation is very effective seismic control measures.

ACKNOWLEDGMENT

I am thankful to my guide and Head of Department Dr. N. L. Shelke in Civil Engineering Department for his constant encouragement and able guidance. Dr. Ashok S. Kasnale, Principal, Dr. D Y Patil School of Engineering and Technology, Pune-412 105, for his support and facilities provided during the course. I would also like to thank all staff members of Civil Engineering Department. Also, I thank my parents, friends etc. for their continuous support in making this work complete.

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