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Study on Floating Column of High-Rise Building with Isolators and without Isolators

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***Abstract**: The present buildings `with floating column is a typical feature in the modern multi-story construction in urban India. There are many projects in which floating columns are adopted, especially above the ground floor, where transfer girders are employed, so that more open space is available in the ground floor. The basic idea of seismic isolation is based on reduction of the earthquake induced inertia loads by shifting the fundamental period of the structure out of dangerous resonance range, and concentration of the deformation and energy dissipation demands at the isolation and energy dissipation systems, which are design for this purpose.*

The present investigation is about comparison & seismic analysis of regular and irregular structures of 10-storey building by providing with isolators and without isolators and design of lead rubber isolators to isolate ground motion and energy during earthquake. The seismic response are evaluated by using equivalent static analysis, response spectrum analysis and linear time history analysis for bhuj earthquake data on Zone -V. Analysis & results in the high-rise building such as inter storey drifts, storey displacement, and base shear were determined. The floating column structures more vulnerable to earthquake this can be effectively brings down by isolator. In the analysis, base shear forces, storey shear forces and inter storey drifts are compared and results are discussed. Hence from the study, it can be concluded that response from the floating column structure are effectively reduced by the application of base isolator. Design and analysis was carried out by using extended three dimensional analysis of building systems (ETABS) Software.

1. Introduction

A column is supposed to be a vertical member starting from foundation level and transferring the load to the ground. The term floating column is also a vertical element which at its lower level rests on a beam which is a horizontal member. Buildings with columns that hang or float on beams at an intermediate storey and do not go all the way to the foundation and have discontinuities in the load transfer path. The beams in turn transfer the load to other columns below it. Such columns the load was considered as a point load.

The previous Earthquake data provides enough evidence for behavior of different types of structures under different seismic conditions and foundation aspects has become stuff for Engineers and Scientists. This has given various types of innovative techniques to save structures from seismic effects. Among those, Base Isolation is one of the recent techniques. The main aim of base isolation is to provide flexibility and dissipation of energy by incorporating the isolated devices so called isolators, which is provided between the foundation and the super structure. Thus, base isolation essentially dissociates the building from the ground during seismic excitation. The use of flexible layer by base isolation systems at the base of the structure will allow relative displacements between the foundation and the superstructure. Addition of isolation layer elongates the fundamental time period of the structure so as to move away from the ascendant time periods of motion of ground, it means that decreasing the acceleration induced in the

1.1. Concept of Floating Column

A column is supposed to be a vertical member starting from foundation level and transferring the load to the ground. The term floating column is also a vertical element which (due to architectural design/ site situation) at its lower level (termination Level) rests on a beam which is a horizontal member. The beams in turn transfer the load to other columns below it.

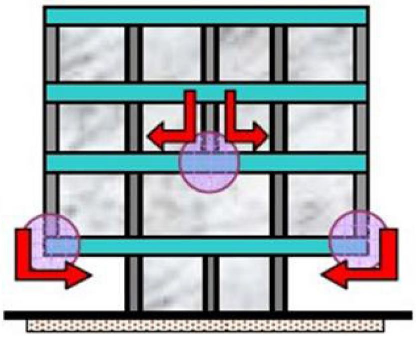

Figure 1. Hanging or floating column.

1.2. Concept of Base Isolation

The basic concept in seismic isolation is to protect the structure from the damaging effects of an earthquake by introducing a flexible support isolating the building from the shaking ground. The base isolation system introduces a layer of low lateral stiffness between the structure and the foundation. With this isolation layer the structure has a natural period which is much longer than its fixed base natural period. This lengthening of the period can reduce the pseudo-acceleration and hence the earthquake induced forces in the structure. In buildings, the base isolator protects the structure from earthquake forces in two ways by deflecting the seismic energy and by absorbing the seismic energy. The seismic energy is deflected by making the base of the building flexible (instead of fixed) in lateral directions, thereby increasing the fundamental time period of the structure.

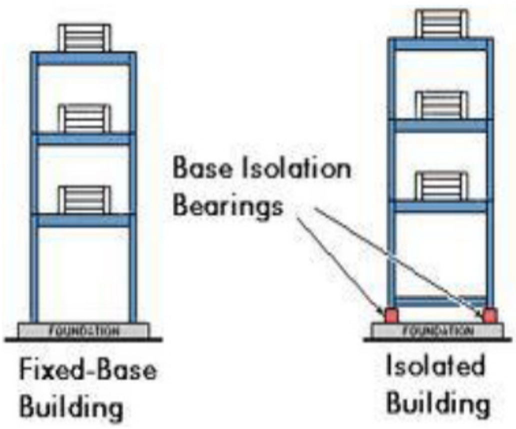

Figure 2. Function of base isolation.

1.3. Principle of Base Isolation

The essential goal with seismic isolation is to introduce horizontally flexible but vertically stiff components in between the structure and ground by that substantially uncouple the superstructure from high-frequency earthquake shaking. The essential idea of base isolation framework is extending the natural period of fixed base building. The ultimate purpose of isolating the structure is reduction of seismic force on the structure. This reduction in seismic forces is done in part by observing the superstructure's spectral accelerations. These accelerations are decreased both by lengthen the effective fundamental period of the isolated structure and through damping caused by energy dissipated within the isolation bearings. The effect on spectral acceleration of these two approaches is shown in figure below.

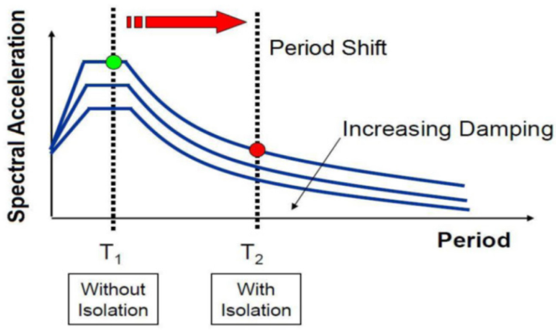

Figure 3. Period shift effect of fixed base and base isolated building.

1.4. Types of Base Isolators

The most common use of base isolator in building is

1. Laminated Rubber (Elastomeric) Bearing
2. Lead Rubber bearing (LRB)
3. Friction Pendulum (FPS) system Bearing

1.5. Design of lead rubber bearing (LRB)

There are large numbers of isolation devices including elastomeric, sliding and laminated rubber bearing have been developed and utilized essentially for seismic configuration of structures amid the most recent 25 years. Among these available isolators the lead rubber bearing (LRB) had been utilized broadly. It comprises of substitute layers of elastic and steel plate and inserted a lead plug one or more into the holes. The bilinear response given by lead core deforming in shear furthermore gives initial rigidity against minor earthquakes and strong winds. The steel plates in the elastomeric bearing gives large plastic deformations. In this way a rubber bearing was then supplanted by lead plug and was tested. The lead is elastic material when hot-worked it plastically deforms at ambient temperature and mechanical properties of the lead restored by the process of re crystallization, recovery and grain growth. As lead deforms at 20°C is also equal to deformation of steel at more than 400°C. Lead is manufactured in steel plates and rubber sheets before they are joined together.

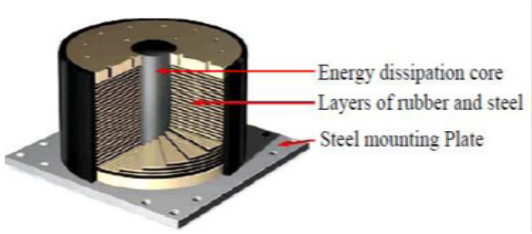

Figure 4. Lead rubber bearing.

Design of lead rubber bearing is manually calculated as per guidelines in the reference paper 4 to obtain parameters of LRB. The parameters of LRB are shown in below table.

Table 1. Parameters of LRB.

Required stiffness or Effective stiffness (K_{eff})	902.65 kN/m
Horizontal bearing stiffness (K_b)	363.43 kN/m
Vertical stiffness	161.80 kN/m
Yield force (F)	28.21 kN
Stiffness ratio	0.17
Damping	0.05

1.6. Aim and Scope of Study

- The goal of this work is to study the behavior of multi-storey buildings with floating columns under earthquake excitations.
- The essential point of this work is to study the response of multi-storey structures with floating column with fixed base and with isolators.
- Study of seismic demands of regular and irregular R C buildings using time history analysis.
- To evaluate the effect of floating column and base isolator on the seismic performance of the 10-storey buildings located in Zone-V.
- To carry out modeling and analysis of fixed base and base isolated buildings by using ETABS software and study the effects of earthquake ground motions.
- To design and study the effectiveness of lead rubber bearing used as base isolation system.
- To carry out comparison between fixed base and base isolated building on the basis of their dynamic properties like maximum storey shear force, maximum inter stoery drift and lateral displacement.

2. Model Description

Structure	- SMRF
Number of stories	- 10m
Building Storey Height	- 4 m
Grade of Concrete	- M25
Grade of steel	- Fe415
Beam Size	- 0.23x0.45 m
Column size	- 0.45x0.45 m
Slab size	- 0.125 m thick
Seismic Zone	- V
Soil condition	- Medium
Importance Factor (I)	- 1
Reduction Factor (R)	- 5
Seismic zone factor (V)	- 0.36
Live Load	- 3 kN/m^2
Roof live load	- 2 kN/m^2
Floor finish for roof	- 1.5 kN/m^2
Floor finish on floor	- 1.2 kN/m^2

All columns are assumed to be fixed at they are replaced with lead rubber isolator.

In present thesis four models considered are Regular building plan(M1), Regular building with floating column(M2), irregular building plan(M3) and irregular building with floating column(M4). The linear static, response spectrum and time history methods are applied for the analysis. The analysis is carried out by standard finite element software ETABS.

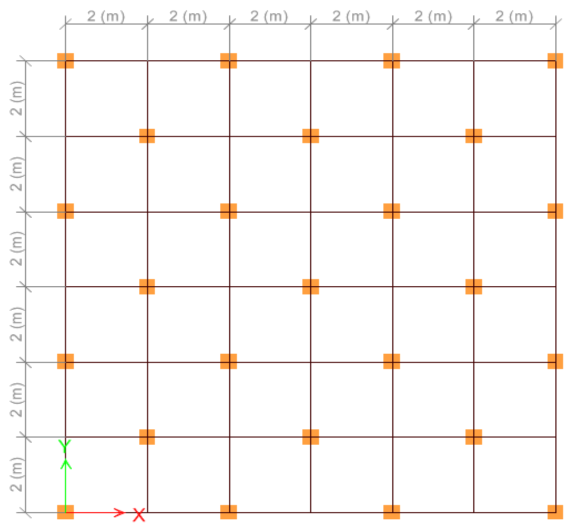

Figure 5. Regular building with floating column (M2).

3. Results and Discussion

Results obtained by each models are discussed in this chapter. The analysis carried out by equivalent static, response spectrum and time history method. The parameters discussed in this study include Lateral displacement, inter storey drift, base shear and time period. Parameters of different models of fixed base building are compared with the parameters of different models of base isolated building. The following figures shows results obtained from time history method.

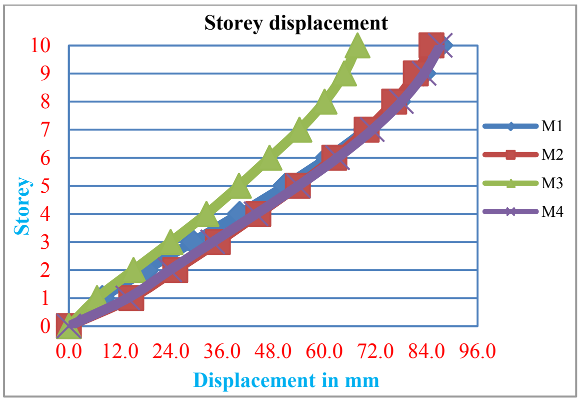

Figure6. Lateral displacement in mm.

Above graph shows the maximum lateral displacement. The displacement values of models M1 and M4 are 3% & 22% more as compared with M2 and M3.

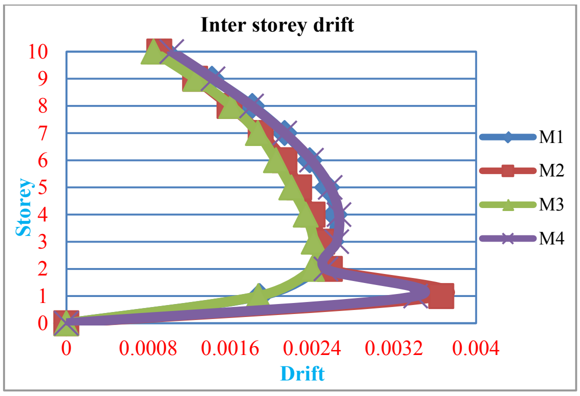

Figure 7. Inter storey drift.

Above graph represents inter storey drift of considered models. It is seen that drift values are increased to 30%, 29%, in M2 & M4 as compared to M1 & M3.

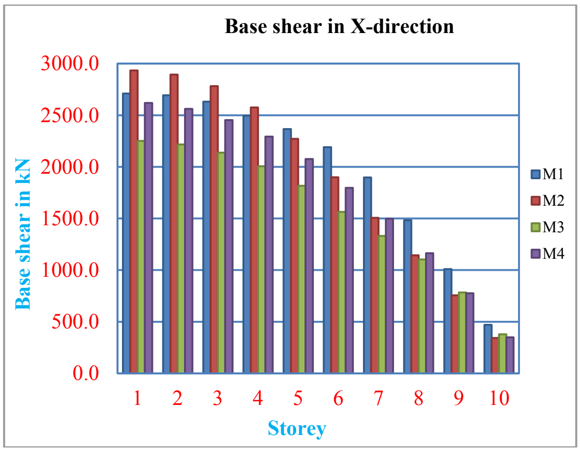

Figure 8. Base shear in kN

Above graph represents inter storey drift of considered models.There is increase in base shear in model M2 & M4 as 8% & 14% when compared with M1and M3.

3.1.comparison of fixed base building and base isolated building results

After the analysis with floating column and without floating models base reaction is taken and from those base reaction parameters of LRB is calculated. Calculated parameters are applied to each column and earthquake analysis is done and results are plotted in graphs. The following graphs represent the results of time history method.

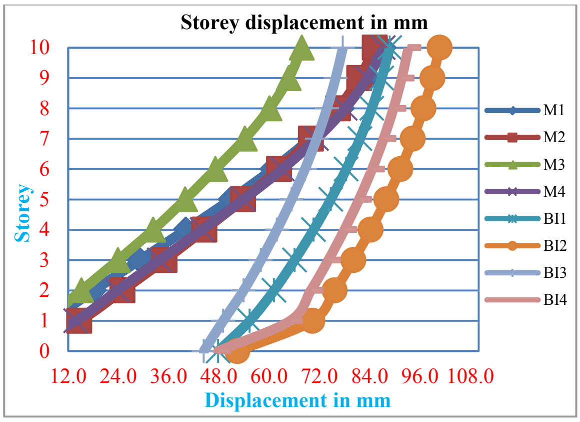

Figure 9. Comparison of lateral displacement of fixed models and base isolated models in mm.

Above graph shows the maximum displacement of fixed base models and base isolated models. The displacement of base isolated models is low as compared to fixed base models and it is observed that displacement in M1, M2, M3, M4 decreased by 53%, 43%, 51%, 48% as compared with BI1, BI2, BI3, BI4.

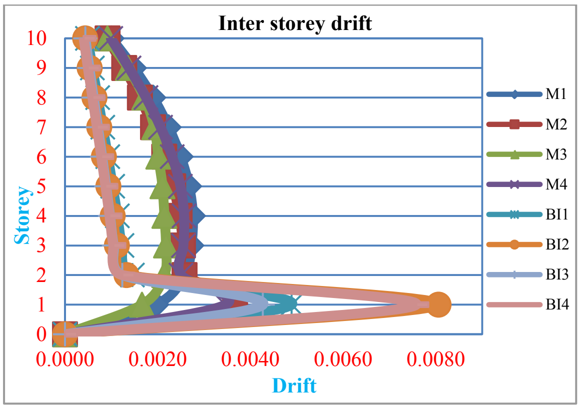

Figure 10. Comparison of Inter storey drifts of fixed models and base isolated models.

Above graph shows the maximum inter storey drift of fixed base models and base isolated models. Inter storey drift is reduced for all the floors in each of the model for base isolated model compared to fixed base model and There is decrease in inter storey drift in models of base isolation by 36%, 52%, 43% and 51% as compared with fixed base models.

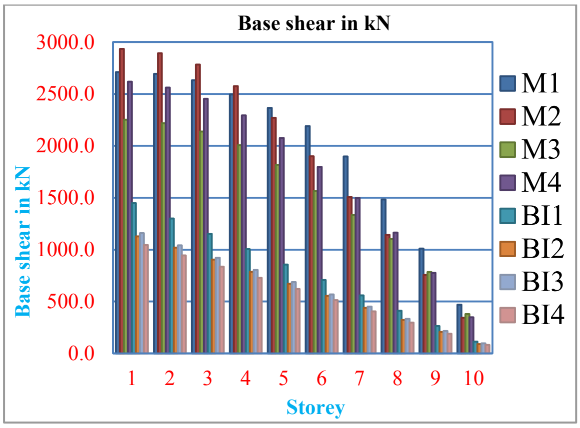

Figure 11. Comparison of Base shear of fixed models and base isolated models in kN.

The above graph shows the graph of base shear values for the base isolated models and fixed base models. It is seen that decrease of base shear in base isolated models when compared with fixed models. It is also seen that reduction of base shear in base isolated models is almost 47%, 61%, 48% and 53% when compared with fixed base models.

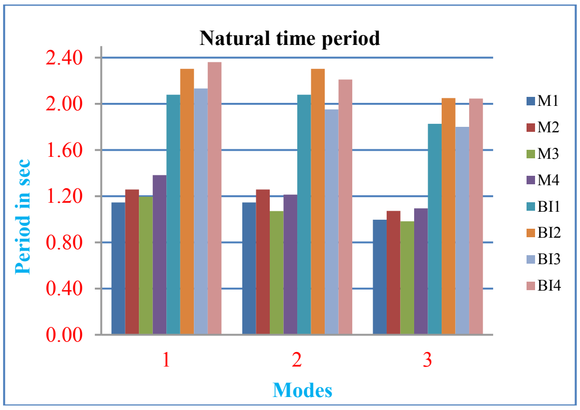

Figure 7. Natural time periods in seconds.

The above graph shows the graph of natural time periods values for the base isolated models and fixed base models. The time period of the base isolated structure in around twice the time period of fixed base models and also time period shifts almost 0.93 to 1.04 seconds in base isolated models when compared with fixed base models.

4. Conclusion

This study presents the study of comparison without floating column and with floating column structures and design of seismic isolation systems and influence of base isolation on the response of structure under seismic loading. Based on analysis results and graphs following conclusions are made.

1. By the applications of lateral loads in X and Y direction at each floor, the lateral displacements of floating column building are more compared to that of normal building.
2. Lateral displacements are more in time history analysis compared with other two method of analysis.
3. Maximum displacement is increased in floating column model when compared with without floating column model.
4. Inter storey drift at each floor for the building it is seen that building with floating column will experience extreme inter storey drift than the normal building.
5. The inter storey drift is maximum at 3rd level in without floating column model and 1st level in with floating column model in three cases of analysis.
6. Inter storey drift are more in time history case as compared with other two methods.
7. The inter storey drift is more for the floating column buildings because as the columns are removed the stiffness gets reduced on respective floor.

8. The building with floating columns experienced more storey shear than that of the normal building. This will increase the structural member sizes. So the floating column building is uneconomical to that of a normal building.
9. Base shear increases with the increase of mass and number of story of the building, also base shear obtained from time history analysis is much more than the base shear obtained from other two methods.
10. Structures with short natural period will suffer higher accelerations. Thus the increase in period of the structure with isolated base makes sure that the structure is completely safe from the resonance range of the earthquake.
11. The decrease in the base shear in base isolated model compared to fixed base models is due to the decrease in spectral acceleration values due to the period shift.
12. It is seen that the relative displacement between stories after using isolator is much less than before. This clearly indicates that the axial force on column will be reduced which will reduce the design reinforcement for column. So, Base isolation is economical under design consideration.
13. Inter storey drift of all models are within permissible limit i.e. 0.004h as per IS 1893-2002.

5. Future Scope of Study

1. Different types of dampers can be adopted for analysis of structures.
2. Comparison can be made between the performances of different base isolators using floating column structures.
3. Pushover analysis for floating column and base isolated structures can also be performed.

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