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Dynamic Analysis of 3D RC Frame with Base Isolator

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***Abstract*— This article presents an outline of the base isolation techniques with special emphasis for reducing earthquake forces on the structures. Base isolation is an anti-seismic design strategy that can reduce the effect of earthquake ground motion by isolating the superstructure from the foundation. The important feature of the base isolation technique is that it introduces flexibility to the structure. In this paper linear static and linear dynamic analysis of 3D R.C building models of G+10, G+15 and G+ 20 storeys situated in all seismic zones is carried out by providing base isolator. The base isolator considered here is Lead Rubber bearing (LRB) system and it is designed by taking maximum vertical reaction from analysis.**

The FE analysis involving Modal, Equivalent static and Response spectrum are carried out for both fixed base and base isolated models and the results obtained are in terms of natural time period, mode shapes, base shear, storey displacement and storey drift. All the results are tabulated, discussed and conclusions are drawn.

***Index Terms*— Base Isolation (BI), Fixed Base (FB), Lead Rubber Bearing (LRB), Modal Analysis, Response.**

I. INTRODUCTION

Base isolation is defined as a flexible material Pertaining to passive control system and which is provided at base to reduce the seismic forces of any structure. Isolators are provided at the base which results in reduction of ground motion transmitted to the superstructure above isolator, reducing the response of a typical structure and corresponding loading. They are located strategically between the foundation and the building structure and are designed to lower the Magnitude and frequency of seismic shock permitted to enter the building. They are provided with both spring and energy absorbing characteristics. Fig.1 illustrates the behaviour change of structure with and without isolator incorporation.

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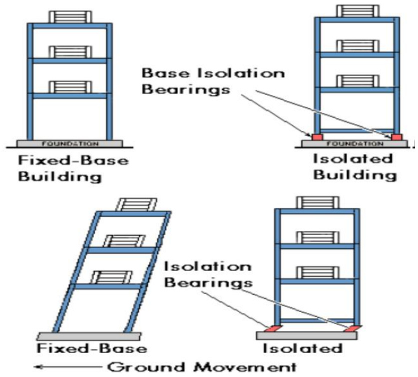

Fig.1 Fixed base v/s Base-isolated building

II. OBJECTIVES

The work includes analysis of G+10, G+15 and G+20 storey reinforced concrete symmetric frames in accordance with IS 1893:2002 provisions; one with fixed base and other is base isolated.

The objectives of this work are as follows:

- To carry out modeling and analysis of fixed base and base isolated buildings by using E-TABS software and study the effects of earthquake ground motions on these models.
- To design and study the effectiveness of lead rubber bearing used as base isolation system.
- To measure the Vibration Parameters such as Natural time period, Mode shapes of a selected 3D RC frame analytically by carrying out Modal analysis.
- To Measure the dynamic properties such as Base shear, Storey Displacement and storey drift by carrying out Response Spectrum analysis.
- To carry out comparison between fixed base and base isolated building on the basis of their dynamic properties and vibration properties for different earthquake zones and for varying storey heights.

III. METHODOLOGY

A. Modeling:

Modeling is carried out using ETABS (Extended 3D analysis of building system) software of version 9.7.1.

B. Salient Features of the Building:

TABLE.I: CONSTANT PARAMETERS OF BUILDING

Type of structure	Commercial
Number of stories	10, 15, 20
Height of typical floor	3m
Beam size	700mm*400mm
Slab thickness	150mm
Masonry wall thickness	230mm
Characteristic strength of concrete, f_{ck}	25N/mm^2
Grade of Steel	415N/mm^2
Density of Concrete	25 kN/m^3
Modulus Elasticity of Concrete	25000N/mm^2
Poisons ration of Concrete	0.3
Density of brick masonry	19 kN/m^3
Modulus Elasticity of Brick Masonry	14000N/mm^2
Poisons ratio of Brick Masonry	0.2
Earthquake Zones	II, III, IV, V
Importance factor	1
Response reduction factor	5
Damping ratio	10%
Live load	3 kN/m^2

Thecolumn size is 400mm*400mm, 500mm*500mm and 600mm*600mm for 10, 15 and 20 storey building respectively.

Types of models considered for the case study are

- Model-1: Fixed RC bare frame (FB)
- Model-2: RC bare frame with LRB (LRB)

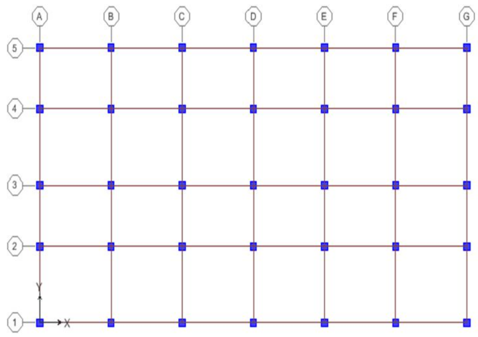

Fig.2: Plan

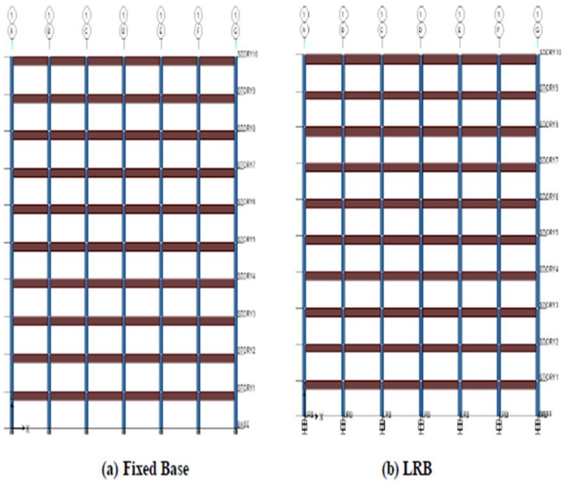

Fig 3: Elevation

C. Link properties

The isolator considered in this work is Lead Rubber Bearing and designed follow the available recommendations of the ―Earthquake Engineering Handbook by W.H Chen and Charles Scawthorn. The mechanical properties of the LRB isolation system are set to comply with the recommendation of the Earthquake handbook. The design parameters considered are: Vertical stiffness (KV), Horizontal stiffness (KH), Pre yield stiffness (KU), Yield force of lead plug (Qd) and Post Yield Stiffness Ratio. The values obtained are tabulated in the Table.2

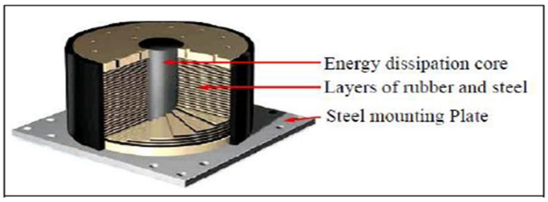

Fig.3: Lead Rubber Bearing

TABLE.II: LEAD RUBBER BEARING AND ISOLATOR PARAMETERS

Parameters	G+10	G+15	G+20
U1 Linear Effective Stiffness (kN/m)	68.28×10^4	99.44×10^4	12.92×10^5
U2 and U3 Linear Effective Stiffness (kN/m)	1721.56	2587.19	3521.05
U2 and U3 Nonlinear Stiffness (kN/m)	14511.03	21807.3	29678.94
U2 and U3 Yield Strength (kN)	55.9	84.14	114.51
U2 and U3 Post Yield Stiffness Ratio	0.1	0.1	0.1

IV. ANALYSIS

- Modal analysis
- Equivalent static analysis
- Response spectrum analysis

V. RESULTS AND DISCUSSION

In this paper the performance of base isolated structure is studied under seismic loading. The design of lead rubber bearing is done and the model is created for FE analysis which includes modal and response spectrum analysis.
Regular fixed base structure is considered for FE analysis so that the results can be compared with the base isolated structures. The results obtained are natural time period, mode shapes, base shear, displacement and storey drift. All the results are tabulated and discussed.

A. Natural Time Period

Fundamental time period calculated as per IS 1893-2002 and modal analysis results are tabulated in Table.3 and the graph showing time period versus models are shown in Fig.4.

TABLE.II: NATURAL TIME PERIOD BY CODAL AND ANALYTICAL METHOD (SEC)

Model type	G+10		G+15		G+20	
	Codal	Modal	Codal	Modal	Codal	Modal
FB	1.03	1.41	1.37	1.82	1.68	2.32
BI		3.12		3.37		3.72

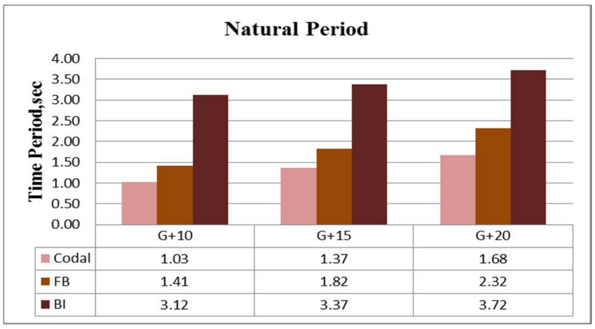

Fig.4: Time period of all the models from modal and codal analysis

From Table.2 and Fig.4 following are the observations

- As the height of the structures increases natural time period also increases both in codal and modal analysis.
- Codal and analytical values follows the same pattern but values obtained do not tally with each other. The seismic code IS: 1893-2002 (Part I) underestimates in calculating natural time period.
- The time period of the base isolated structure in around twice the time period of fixed base model and also the time period shifts away from the dominant periods of earthquake i.e. o.2 to 0.5sec.

B. Base Shear

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure. The base shear is a function of mass, stiffness, height, and the natural frequency of the building structure.
The storey height vs. base shear graph for G+10, G+15 and G+20 storey, fixed base and base isolated models are shown in Fig.5.
From the Fig.5 followings are the observations

- As the height increases, base shear also increases for all models.
- The decrease in the base shear in base isolated model compared to fixed base models is due to the decrease in Sa/g values due to the higher time period values.
- Base shear of the isolated building is reduced to 48%, 39% and 32% of the fixed base models in case G+10, G+15 and G+20-Storey building respectively in all seismic Zones.

The seismic demand of the structure to be considered during design is drastically decreased

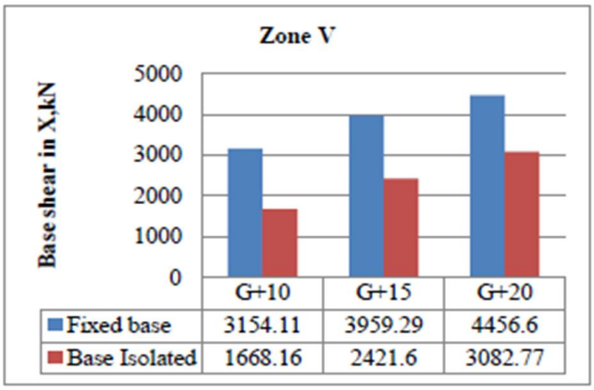

Fig.5: Base Shear vs. storey height in Zone-V

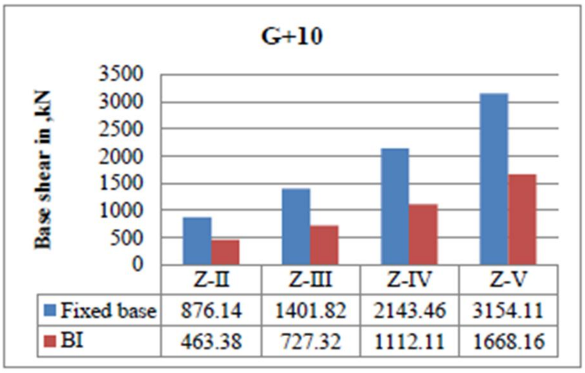

Fig .6: Base Shears vs. Zone for 3D RC Frame FB and BI Models

The Fig.6 shows plot of base shear versus different seismic zones for 3D RC frame fixed base and base isolated models for 10 storey building. It can be observed that the value of Base shear increases as the seismic intensity of zones increases in case of both fixed base and base isolated models.

C. Storey Displacement

The storey height vs. displacement graph for G+10, G+15 and G+ 20 storeys with fixed base and base isolated models are shown in Fig.7, 8 and 9 respectively.

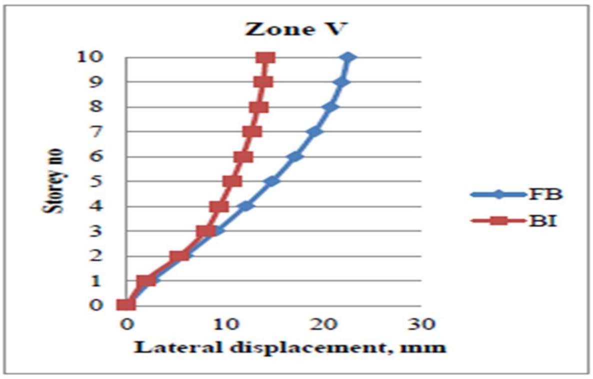

Fig.7: Displacement vs. storey height forG+10-Storey in Zone-V

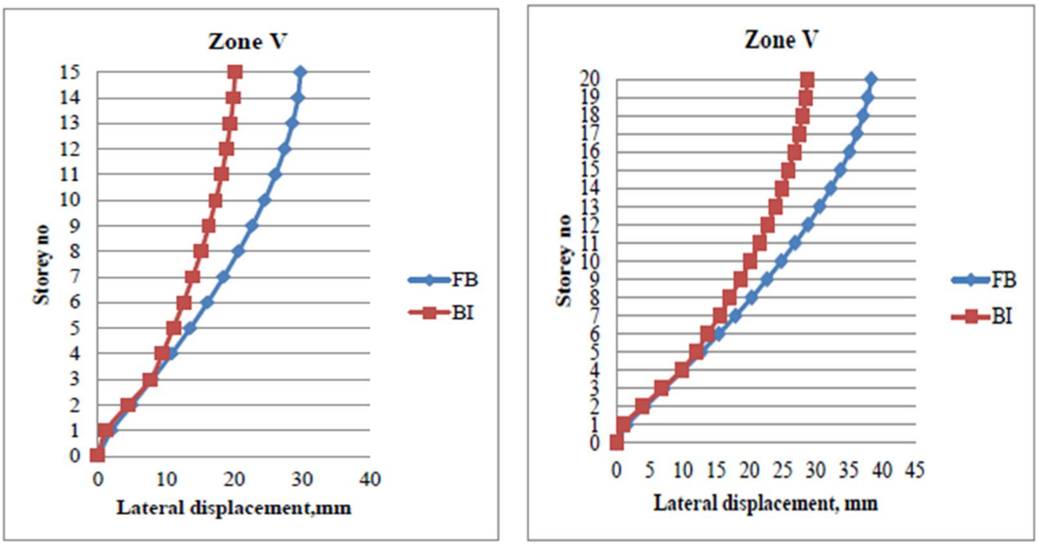

Fig.8: Displacement vs. storey height for G+15 and G+20-Storey in Zone-V

From fig.7, & 8 following are the observations

- The results of displacement shows that the displacements are increased with the Time period and with the storey height in the base isolated building.
- The displacement of base isolated models is less compared to fixed base models for the storey heights.
- Lateral displacement at the roof of the isolated building is reduced to almost 47%, 35% and 30% when compared to fixed base models in case G+10, G+15 and G+20-Storey buildings respectively in Zone V.
- As the height increases the effects of base isolation reduces in decreasing the displacement.

It is observed 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.

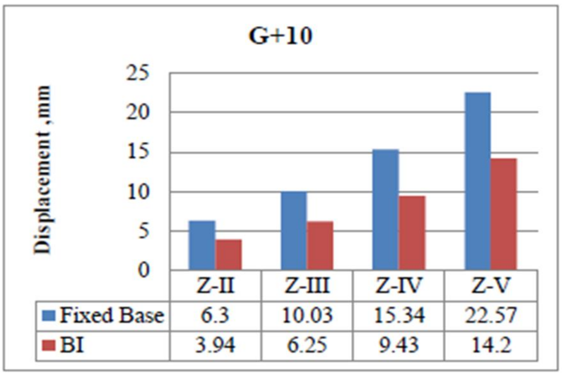

Fig .9: Maximum Displacements vs. Zone for 10-Storey models

From the above figure it can be observed that the value of displacement increases as the seismic intensity of zones increases and is maximum for zone V.

D. Storey Drift

According to IS 1893(Part 1):2002 clause 7.11.1, the storey drift is the displacement of one level relative to the other level above or below. Storey drifts limitations are explained that the Storey drifts in any storey due to the minimum specified design lateral force, with partial load factor of 1.0 shall not exceed 0.004 times the storey height.

The storey height vs. storey drift graph for G+10, G+15 and G+ 20 storeys with fixed base and base isolated models are shown in Fig.12, 13 and 14 respectively.

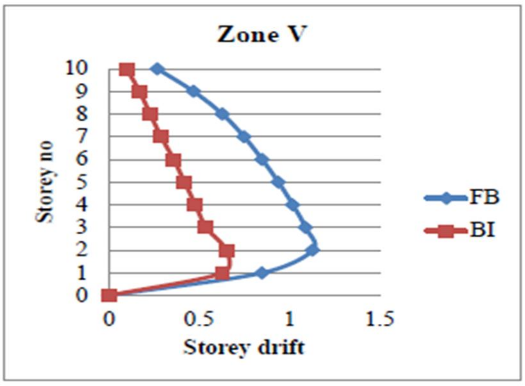

Fig 10: Storey Drift vs. storey height for G+10-Storey in Zone-V

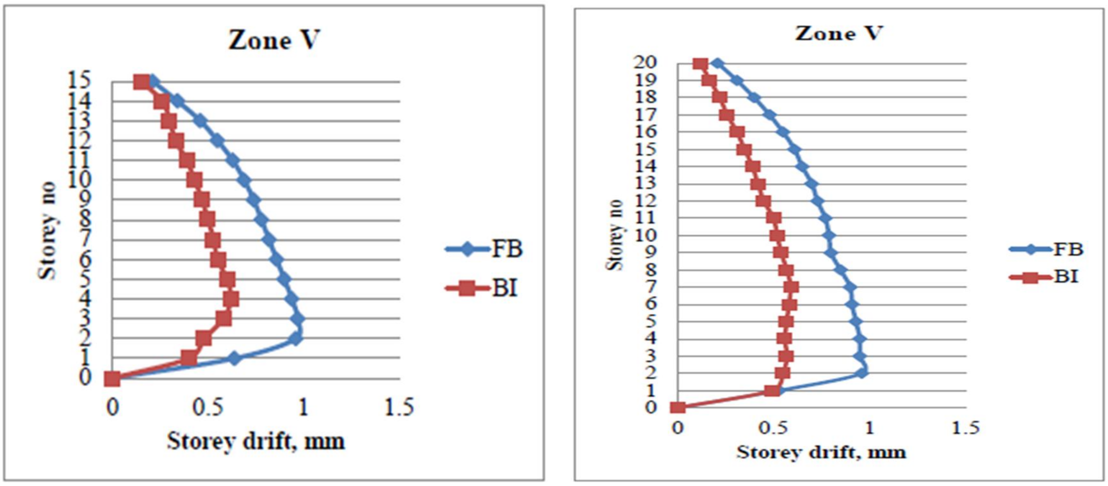

Fig .11: Storey Drift vs. storey height for G+15 and G+20-Storey in Zone-V

From the table Fig.10, 12 and 13 followings are the observations

- The results of displacement shows that the storey drifts are increased with the storey height in the base isolated building.
- Story Drift is less for all the floors in each of the model for base isolated model compared to fixed base model.
- Maximum Storey drift of the isolated building is reduced to almost 43%, 40% and 24% compared to fixed base models in case G+10, G+15 and G+20-Storey building respectively in Zone V.
- As the height increases the effects of base isolation reduces in decreasing the storey drift.

Storey drift of all models are within permissible limit i.e.0.004h as per IS 1893-2002

VI. Conclusions

A. Shift in Time Period

After providing rubber base isolator the time period of the base isolated structure is found to be in around twice the time period of fixed base model and also the time period shifts away from the dominant periods of earthquake i.e. o.2 to 0.5sec.
It is investigated that the mode period is increased after providing rubber isolator due to the flexible property of the isolator

B. Reduction in Base Shear

The decrease in the base shear in base isolated model compared to fixed base models is due to the decrease in Sa/g values due to the higher time period values.

C. Reduction in Displacement

The significant characteristic of base isolation a system affect the superstructure to have a rigid movement and as a result shows the relative story displacement & story drift of structural element will decrease.

All fixed base building have zero displacement at base of the building whereas in case of base isolated model appreciable amount of lateral displacement was observed at the base. Also it has been observed that as floor height increases, lateral displacements increases drastically in case of fixed base building. But for base isolated buildings the lateral displacement variation is smaller as the height increases.

D. Reduction in Storey Drift

Apart from the first floor, the relative storey drifts is significantly reduced especially in the fixed-base alternative due to the corresponding reduction in storey displacement. This situation indicates that the superstructure exhibits behavior close to rigid body behavior in base isolation.

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