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Earthquake Response of RCC Frames with and without bracing using Base Isolation Techniques

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Abstract*: Among different natural hazards, earthquake is one of the most destructive threats which has a severe effect on the safety and welfare of human beings. Base isolation is one of the most effective methods for earthquake resistant design to reduce transmission of vibration from ground to the superstructure. The principle of base isolation is to introduce flexibility to the structure. Different studies are in progress to introduce a most suitable model to withstand the natural calamity that effect the building structure. Bracings are used to provide strength, stability and to resist the lateral loads were as the base isolation methods provides passive vibration control. In this study, a six storey building which is situated in Bhuj city is considered. X bracings provided in different sides of structures with and without using lead rubber bearing and friction pendulum bearing as base isolators. Response spectrum analysis carried out for frames with and without bracing using base isolation techniques using the software ETABS2015. Analysis results show a reduction in base shear for base isolated buildings. The storey displacement and time period of base isolated building is increased as compared to that of fixed base structure.

Keywords: Base isolation, Bracing, Friction pendulum bearing, Lead rubber bearing, Response spectrum Analysis, Base shear, Storey displacement, Time period, ETABS2015

I. INTRODUCTION

Among the different natural hazards, earthquake is one of the most devastating threats which has a severe effect on the safety and welfare of human beings. Building which appear to be strong enough found to be crumbling during strong ground motions. For seismic design of building, the traditional method has been in common use for long time. Therefore, the dimensions of structural members and the consumption of materials are expected to be increased, which leads to higher cost of the buildings as well as larger seismic responses due to larger stiffness of the structure. To overcome these disadvantages associated with the traditional method, many vibration control measures, called structural control, have been studied. Structural control is the one of the area of current research aims to reduce structural vibration during loading such as earthquake and strong winds.

In terms of different vibration absorption methods, structural control can be classified into active control, passive control, hybrid control, semi active control and so on. Base isolation is a passive vibration control system that does not require any external power source for its operation and utilizes the motion of the structures to develop the control forces. Base isolation is one of the most popular means of protecting a structure against earthquake forces. It is a collection of structural elements which should substantially decouple a superstructure from its substructure resting on a shaking ground thus providing a building or non-building structure's integrity. The fundamental principle of base isolation is to modify the response of the building so the ground can move below the building without transmitting these motions into the building.

There are several techniques to improve the strength and lateral stability of buildings. Use of steel bracing systems is one of such methods which are highly efficient and economical. A viable solution for enhancing earthquake resistance is to use steel bracing system for strengthening and retrofitting seismically inadequate reinforced concrete frames. By the addition of bracing system, load will transferred out of the frame and passes on to the braces, by passing weak columns while increasing strength. The potential advantages of using steel bracing are their high stregth, stiffness, economical, occupies less space and adds much less weight to the existing structure. The type of steel bracing used for this study is X bracing. X bracings effectively reduces bending moment, shear forces and axial forces on beams and columns. Among different types of base isolation system lead rubber bearing and friction pendulam bearing isolators are used in this study.

Lead rubber bearing is a type of base isolation provides a heavy damping. Heavy damping mechanism incorparated in vibration control technologies and, particularly, in base isolation devices, is often considered a valuable source of suppressing vibrations thus enhancing a building's seismic performance. This is constructed with alternate layers of natural rubber and reinforcing steel plate with a central lead plug. Friction pendulam bearing isolator uses the principle of a pendulam to lengthen the natural time period of the base isolated structure so as to avoid the strongest seismic forces. During an earthquake, the supported structure moves with

small pendulam motions. Since earthquake induces displacements occur primarly in the bearing, lateral loads and shaking movements transmitted to the structure are greatly reduced.

II. NEED FOR THE STUDY

All structures are subjected to vibration due to lateral loads. Structures which are subjected to lateral loads must have adequate stiffness and strength which helps to controlling the deflection and also prevent the damage which may occur. Base isolation is an effective method for earthquake resistant design to reduce vibration transmitted from ground to structures. The principle of base isolation is to introduce flexibility in the structures. In the case of fixed base building, the damage occurs to the structure due to earthquake are very high. But in the case of base isolated building, the damage occurs to the structure is less. So in this study, base isolation techniques are used in the RC bare frame and braced frame structures and analysing their response against seismic forces.

III. SCOPE AND OBJECTIVES

The scope of this study is to perform linear dynamic response spectrum analysis and nonlinear static pushover analysis of RCC frames with and without bracing using base isolation techniques. The seismic analysis of structure with base isolation is carried with following objectives

A. To carry out modelling of fixed base and base isolated building by using the software ETABS 2015.
B. To conduct response spectrum analysis of RCC frames with and without bracings using base isolation techniques.
C. To study the effectiveness of lead rubber bearing and friction pendulum bearing as base isolation system.
D. To carry out comparison between fixed base and base isolated building by response spectrum method.

IV. METHODOLOGY

In this study a six storied commercial building located in Bhuj city in seismic zone V is considered for analysis. Two type of frames used for the analysis are

A. Bare Frame
1) Bare frame with fixed base
2) Bare frame with lead rubber bearing (LRB) at base
3) Bare frame with friction pendulum bearing (FPB) at base

B. Braced Frame
1) Braced frame with fixed base
2) Braced frame with lead rubber bearing at base
3) Braced frame with friction pendulum bearing at base

Table 1 Building description

Type of frame	Special moment resisting frame
Number of storey	6
Zone	V
Importance factor	1.5
Response reduction factor	5
Storey height	3.5m
Size of column	450x750mm
Size of beam	300x600mm
Bracing (X bracing)	ISMB450
Grade of concrete	M25 and M30
Grade of steel	Fe415
Slab thickness	150mm

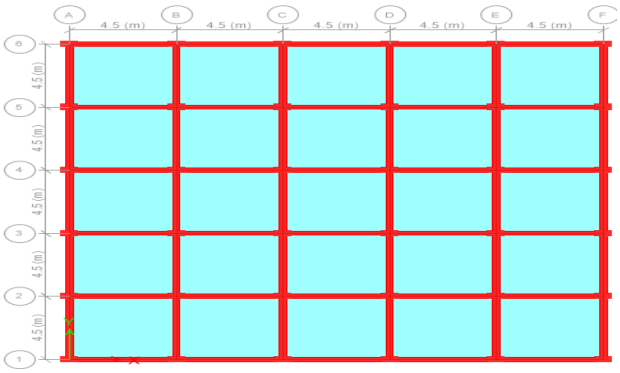

Fig. 1 Building plan

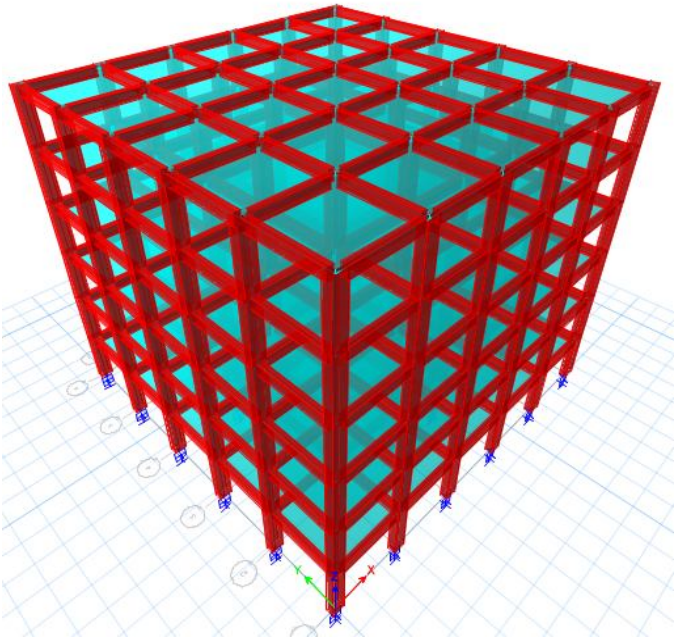

Fig. 2 3D view of bare frame with LRB at base

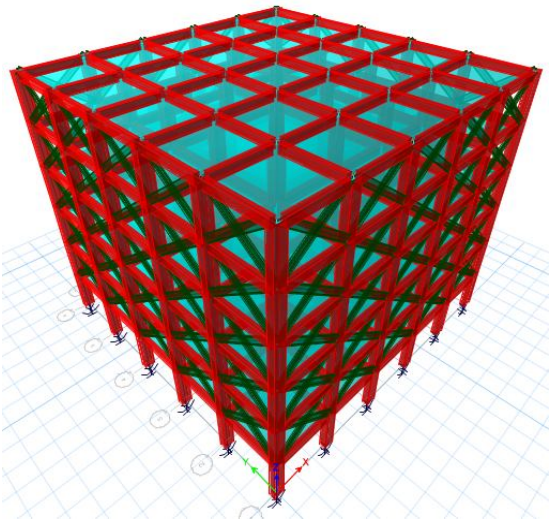

Fig. 3 3D view of braced frame with FPB at base

Table 2 Properties of lead rubber bearing isolator

Property	Values
Effective stiffness, K eff(R)	1763.90kN/m
Horizontal stiffness, KH	1752.60kN/m
Vertical stiffness, KV	623327kN/m
Yield strength, QR	50.94kN
Post yield stiffness	0.1
Damping	5%

Table 3 Properties of friction pendulum bearing

Property	U1	U2	U3
Linear effective stiffness	15000000	750	750
Nonlinear stiffness		15000	15000
Friction coefficient slow		0.03	0.03
Friction coefficient fast		0.05	0.05

V. RESULTS AND DISCUSSION

The response spectrum analysis is performed on bare frame with fixed base, braced frame with fixed base, bare frame with LRB at base, braced frame with LRB at base, bare frame with FPB at base and braced frame with FPB at base. After the analysis maximum storey displacement, base shear and time period for different frames were obtained.

A. Base Shear

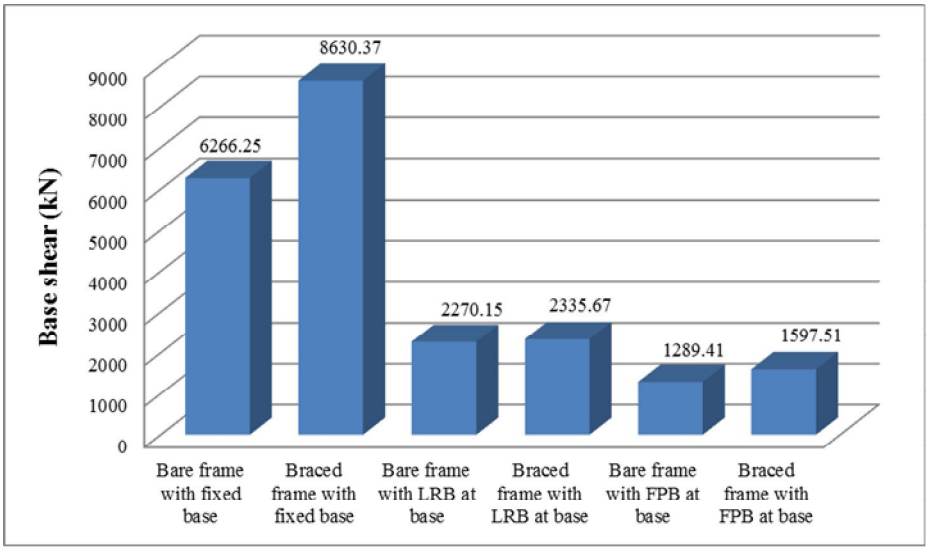

Fig. 4 Comparison of base shear in different models

Fig. 4 shows base shear value obtained for different models after response spectrum analysis. Here the bare frame with friction pendulum bearing at base having least base shear compared to that of other models. Base isolated building tries to reduce base shear more effectively than in the case of fixed base building.

B. Maximum Storey Displacement

A plot which showing the maximum displacement at each of the storey is obtained after response spectrum analysis.

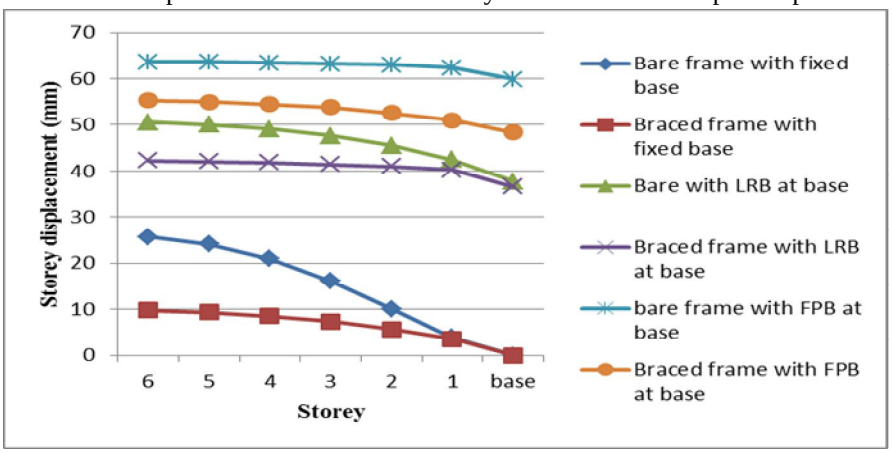

Fig. 5 Comparison of storey displacement for different models

Fig. 5 shows maximum storey displacement for different models obtained after response spectrum analysis. Here fixed base building model have zero displacement at the base of building whereas, base isolated building model shows considerable amount of lateral displacement at base. Also, it has been observed that as floor height increases, lateral displacement increases in fixed base building as compared to that of base isolated building. By the addition of bracing system, the frame reduces the storey displacement as compared to that of bare frame.

C. Time Period

Time period of structure is defined as time taken to complete one oscillation. Usually time period is more for 1st mode shape which is known as fundamental period. Increased time period reduces responses of earthquake. The time period for all the six models after response spectrum analysis is shown in Fig. 6. From the Fig. 6, we can see that the building which is base isolated by friction pendulam bearing isolator at base have increased mode period as compared to that of other frames. The building isolated by providing lead rubber bearing isolator at base also increases the time period as compared to that of fixed base building. By the increase of mode period , it will increases the flexibility of the structure and also reduces the seismic responses of building.

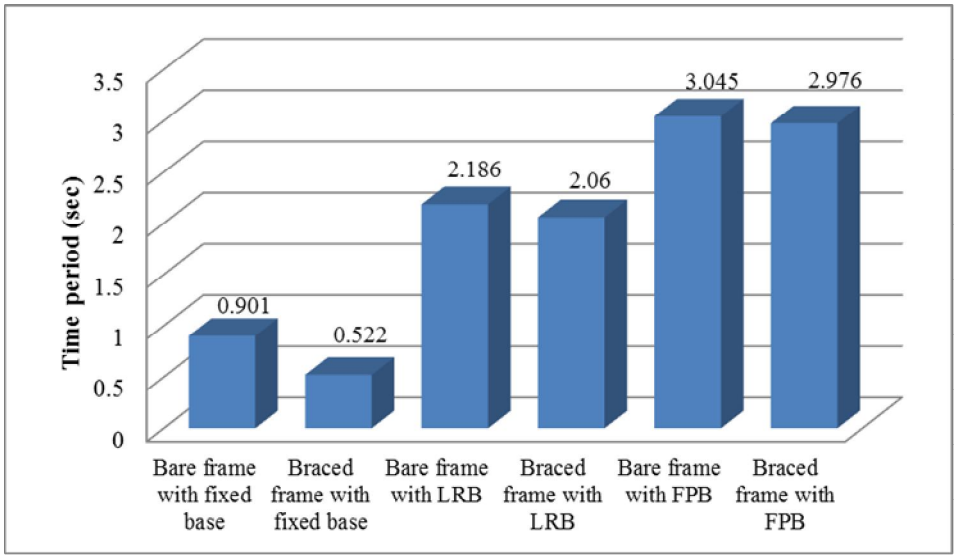

Fig. 6 Time period values for different models

VI. CONCLUSION

The linear dynamic response spectrum analysis of RCC frames with and without bracing using base isolation techniques is considered for finding out various parameters such as storey displacement, base shear and time period. Six types of structures are considered for analysis. After the analysis, following conclusions can be made

A. While comparing the base shear of the structure, it is found that the base isolated building shows a decrease in base shear of about 63.77-81.4% than that of fixed base building. Bare frame with friction pendulam bearing at base has less base shear.

B. While comparing the storey displacement of the structure, it is found that the base isolated structure shows an increase in storey displacement than in the case of fixed base building. Here fixed base building model have zero displacement at the base of building whereas, base isolated building model shows considerable amount of lateral displacement at base. By the addition of bracing system, the frame reduces the storey displacement as compared to that of bare frame.

C. While comparing the time period of the structure, it is found that base isolated building increases the time period of the structure compared to that of fixed base building. In this analysis, bare frame with FPB at base increases the time period as compared to that of other models. This increase of time period is mainly due to the increased displacement of the base isolated building. So it will reduces the seismic responses of the stricture and improves the seismic performance.

D. From the above results, it is clear that base isolated buildings are more effective in resisting lateral forces induced by earthquake. By comparing two isolators, it is clear that friction pendulam bearing is more effective. Because the structure with FPB has higher time period and least base shear.

VII. SCOPE FOR FUTURE WORK

A. Further study can be done by considering other types of base isolators and bracings.

B. Irregular buildings and buildings resting on sloping ground can also be considered for the further study.

C. Other analysis such as time history analysis, pushover analysis and wind analysis can also be done on base isolated structure.

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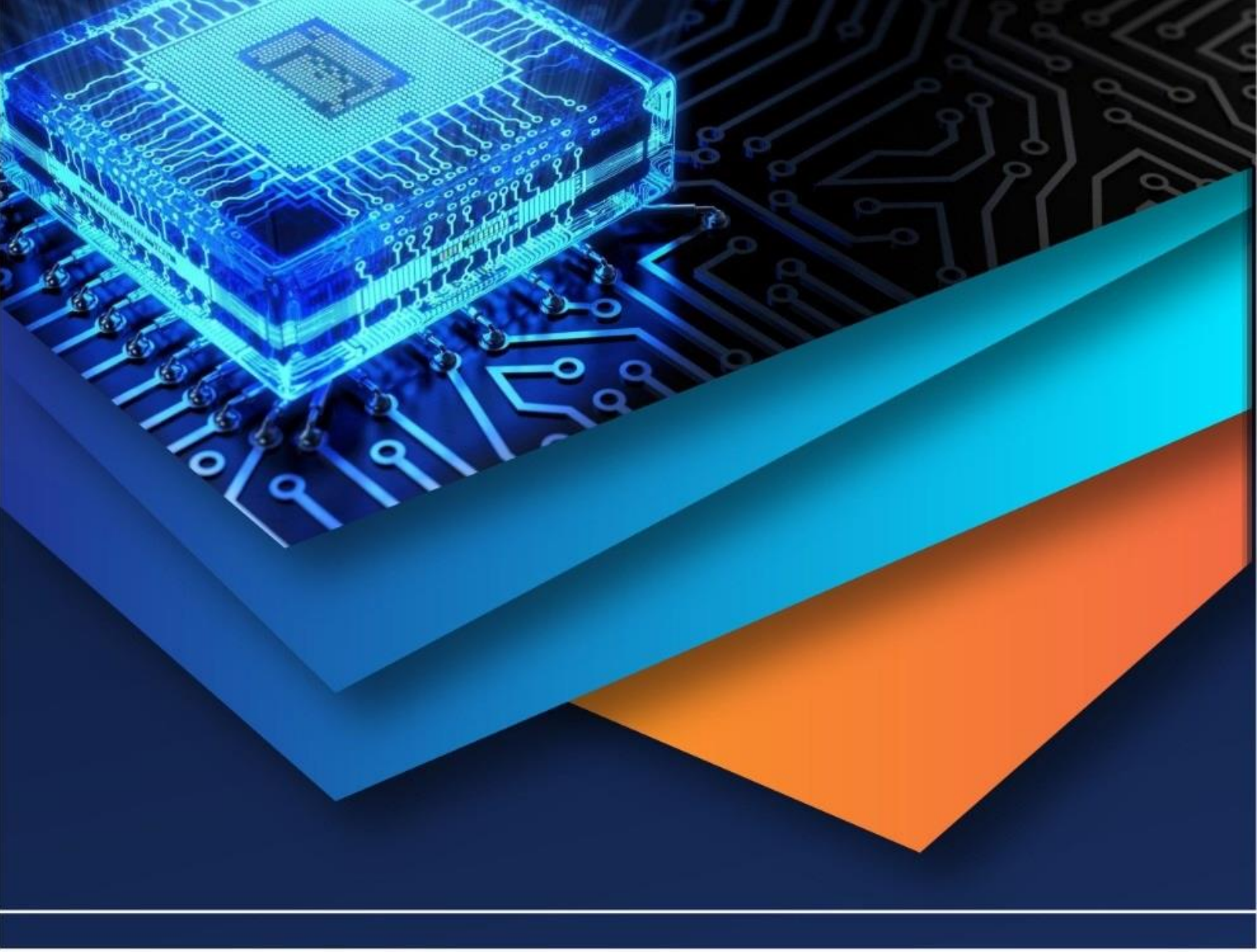

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