

# Base Isolation at Different Levels in Building

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**Abstract:** Base isolation is one of the most popular means of protecting a structure against earthquake forces. It proves to be effective in giving flexibility to the structure by increasing time period of structure and decouples a superstructure from its substructure. The seismic response of multistory building supported on base isolation at different levels is investigated under earthquake time history motion. The purpose of the investigation is to compare in a quantitative manner the relative performance of fixed building and base isolation placed at different levels. A three story building is modeled to compare the response of the two using SAP2000. Time history analysis is conducted for the 1994 Northridge and 1940 El-Centro earthquakes. The analysis result shows that when isolator position is shifting it significantly affects the response quantities. It is possible to arrive at optimum location of the isolator so as to get the maximum benefit of base isolation.

**Keywords:** Laminated rubber bearing; base isolation; earthquake analysis; structural response.

## 1. INTRODUCTION

Earthquake resistance design of reinforced concrete buildings is a continuing area of research since the earthquake engineering has started not only in India but also in other developed countries also. The buildings still damages due to some or the other reason during earthquakes. Behavior of multi-story buildings during earthquake motion depends on distribution of weight, stiffness and strength in both horizontal and vertical planes of building. Conventionally, seismic design of building structures is based on the concept of increasing the resistance capacity of the structures against earthquakes by employing, for example, the use of shear walls, braced frames, or moment-resistant frames.

However, these traditional methods often result in high floor accelerations or large interstory drifts for buildings. Because of this, the building contents and non-structural components may suffer significant damage during a major earthquake even if the structure itself remains basically intact. This is not tolerable for buildings whose contents are more costly and

valuable than the buildings themselves, such as hospitals, police and fire stations and telecommunication centres etc. Therefore, special technique to minimize interstory drifts and floor accelerations, the base isolation technique is increasingly being adopted. Base isolation is to prevent the superstructure of the building from absorbing the earthquake energy.

Therefore, the superstructure must be supported on base isolators to uncouple the ground motion, shown in figure1. Seismic isolation enables the reduction in earthquake forces by lengthening the period of vibration of the structure. Significant benefits obtained from base isolation are in buildings of less than 10 storeys. The natural period of building increases with increasing height. Very tall buildings of more than 18 storeys have high fundamental period and, therefore, do not need to be base isolated. However, more recently considerations like comfort of occupants, functionality of important buildings during and after earthquakes, preventing damage to non-structural elements and contents etc. have attracted the engineers to apply seismic base isolation also for the buildings with 10 to 20 storeys height. There have been proposals to use isolation to new tall buildings and to retrofit buildings with relatively long fixed-base periods, which are deficient in seismic resistance. The main advantage in using isolation system is the reduction in the seismic demand. This could be advantageous if the building is both weak and brittle. [1]

There seems to be a possibility of increasing effectiveness of base isolation for tall buildings by stiffening their superstructure. The stiffening may result in reduced fixed base period and such buildings, if base isolated may develop smaller seismic response. Thus the flexible tall building should be first stiffened to reduce their fixed base period and then base isolated to derive benefit of seismic base isolation. [2] A new concept is developed by shifting base isolator from footing levels to above floors. If it is shifting to above floors accelerations are decreasing therefore less failure occurs to the above floors when compared to base isolation at footing level.

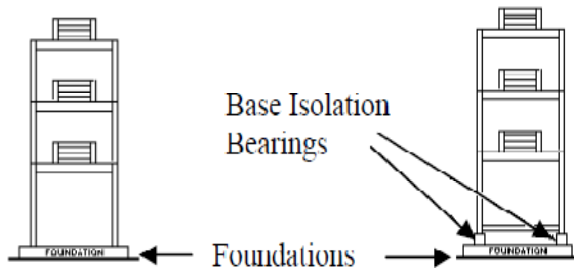


Fig. 5. Base isolation system

## 2. LAMINATED RUBBER BEARING

The laminated rubber bearing (LRB) base-isolation system is the most common base-isolation system. This isolator has been used in a number of buildings in Europe, Japan, and New Zealand. The recently constructed four story Foothill Communities Law and Justice Building in San Bernardino County, California was built on this type of base-isolation system. This bearing is made of alternating layers of rubber and steel with the rubber being vulcanized to the steel plates. Generally, the bearings exhibit high-damping capacity, horizontal flexibility, and high vertical stiffness. Based on test results, the damping ratio depends on the strain levels and may vary from about 0.18 at 2% strain to about 0.10 at 50% strain. The ratio of vertical stiffness and horizontal stiffness should be high and the desired value is in the range of 200 to 500. [3]

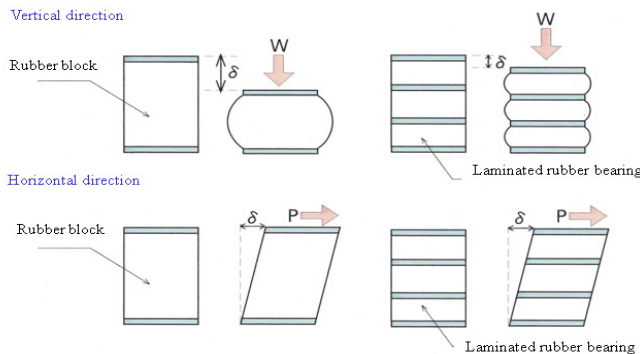


Fig. 2. Laminated rubber bearing.

High damping rubber bearings are composed of rubber layers and thin steel sheets. The damping is increased by adding oils, resins, or other fillers and a damping around 15-20% can be obtained. [4]

## 3. IMPLEMENTATION IN BUILDING

Typical floor plan of base isolated 3 storey reinforced concrete building, which is used as the subject structure in this study as shown in Figure 3. When base isolation provides a more effective and economical alternative than other methods of providing for earthquake safety, then it is used. The first

criterion to consider obviously relates to the level of earthquake risk - if the design for earthquake loads requires strength or detailing that would not otherwise be required for other load conditions then base isolation may be viable. When we evaluate structures which meet this basic criterion, then the best way to assess whether your structure is suitable for isolation is to step through a check list of items which make isolation either more or less effective. [5]

### Weight and mass of the structure

To achieve a given isolated period, a low mass must be associated with a low stiffness. Devices that are used for isolation do not have an infinite range of stiffness. The weight of the structure is obtained by using

All column size = 350X350mm

All beam size = 250X350mm

Slab = 150mm

Height from footing top to Plinth beam bottom = 2.5m

Height of Parapet Wall = 1m

Footing size = 1000X1000X600mm

Floor Height above Plinth beam for all storey = 3.6m

No. of bays in X = direction spanning 5m-5

No. of bays in Y = direction spanning 8m-8

i.e. plan dimensions are 25X64m. All structural members are of concrete with  $F_{ck}=25\text{N/mm}^2$  and the superstructure modal damping ratios are assumed to be constant for each mode as 5%. The three dimensional model of the base isolated building and the time history analyses are made using a well-known software program SAP2000. By calculating all weights finally weight of building is calculated and from which mass is calculated by equation,

$$W=mg$$

Stiffness of rubber isolators

By calculating mass and weight of building we can easily find out the horizontal stiffness of isolators. Stiffness is calculated using the equation,

$$\omega = \text{square root of } (k/m)$$

$$\text{Where, } \omega = 2\pi/T$$

The time period is assumed to be 2.5sec. vertical stiffness is 10 times the horizontal stiffness. Therefore horizontal stiffness is calculated as 6500 and vertical stiffness as 65000.

Time period of structure

The most suitable structures are those with a short natural period, less than about 1 second. For buildings, that is usually less than 10 stories and for flexible types of structure, such as steel moment frames, probably less than 5 stories. As you'll see later, practical isolation systems don't provide an infinite period, rather they shift the period to the 1.5 to 3.5 second

range. If your structure is already in this period range then you won't get much benefit from isolation, although in some cases energy dissipation at the base may help. After running analysis time period for fixed support building found as 0.52sec., for isolated building at ground level it is 2.38sec., for isolated building at plinth level it is 2.11sec., for isolated building at first floor level it is 2.15secs.

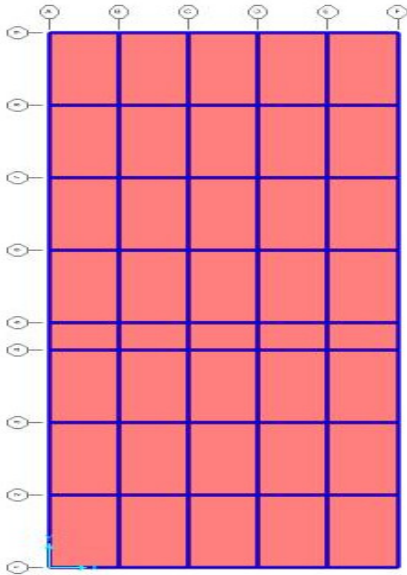


Fig. 3. plan of building

**4. TIME HISTORY ANALYSIS**

Earthquake loads are generated in a building by the accelerations in the ground and so in theory a load specified as a time history of ground accelerations is the most accurate means of representing earthquake actions. Analysis procedures are available to compute the response of a structure to this type of load. Recorded motions from past earthquakes provide information on the possible form of the ground acceleration records but every record is unique and so does not provide knowledge of the motion which may occur at the site from future earthquakes. The time history analysis procedure cannot be applied by using composite, envelope motions, as can be done for the response spectrum procedure. Rather, multiple time histories that together provide a response that envelops the expected motion must be used. Seismology is unlikely ever to be able to predict with precision what motions will occur at a particular site and so multiple time histories are likely to be a feature of this procedure in the foreseeable future.

The earthquake motions are selected for the studies are 1994 Northridge and 1940 El-Centro earthquakes recorded at different stations as the details are given in Table 1. Time history records for different types of earthquake are as below [6]

**TABLE 1: Time history record for different types of earthquake**

EARTHQUAKE	MAGNITUDE	PGA
NORTHRIDGE	6.7	0.514g
EL-CENTRO	6.5	0.327g

**5. COMPARISON OF FIXED BASE AND BASE ISOLATORS AT DIFFERENT LEVELS IN BUILDING**

In this section a comparison of earthquake response of fixed base structure with the base isolators at different levels is made. The output results for El-Centro and Northridge earthquake are in X direction as follows

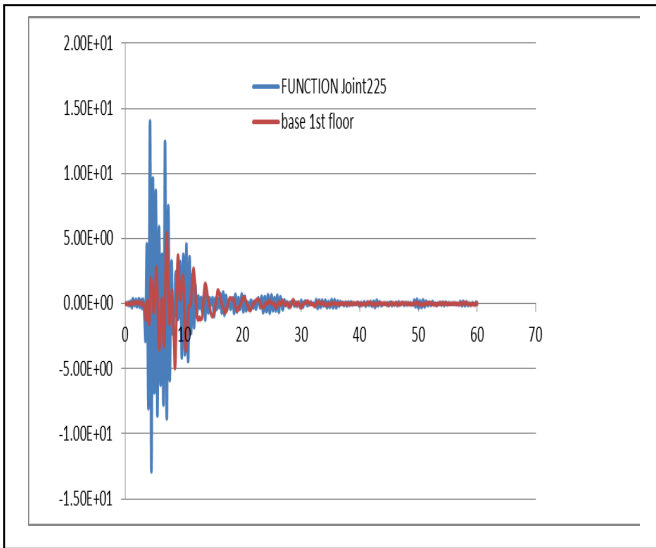
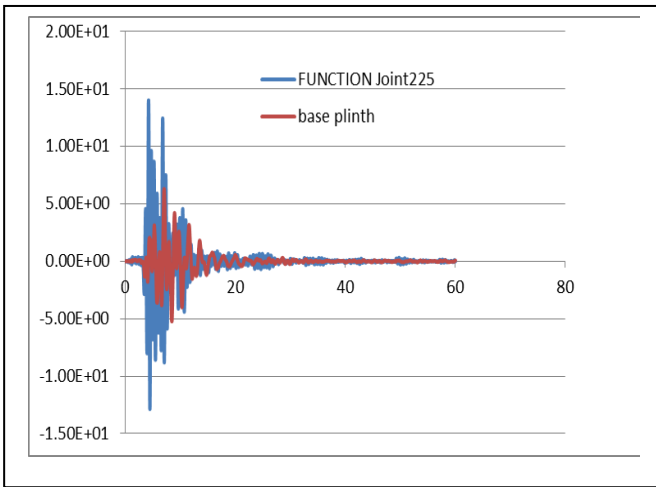
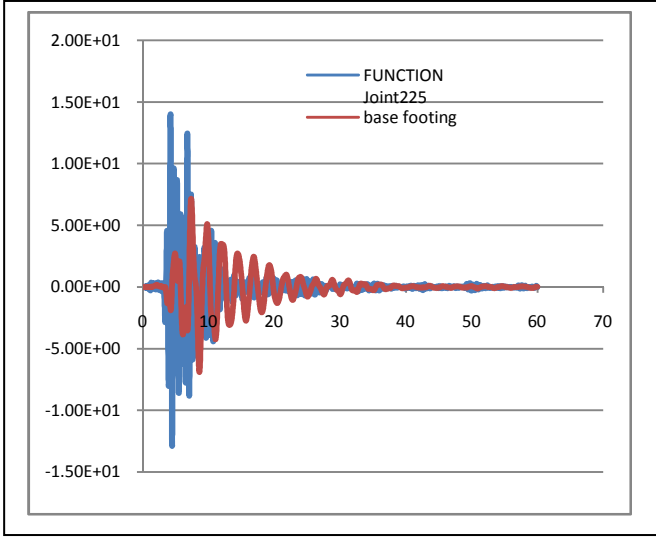
**TABLE 2 Output result for El-Centro and Northridge Earthquake**

Earthquake	Fixed Base Structure		Base isolator at footing level	
	Northridge	El-Centro	Northridge	El-Centro
Acceleration	14.02	8.984	7.163	3.243
Displacement	0.09711	0.063	0.7767	0.349

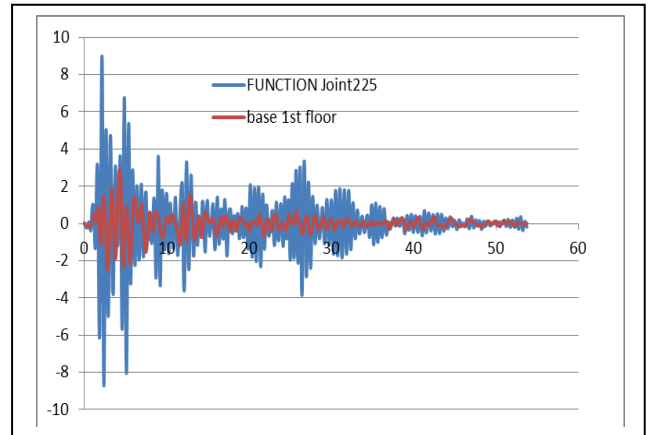
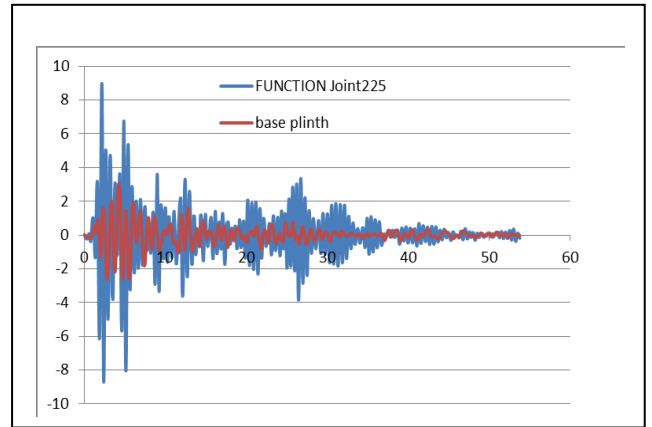
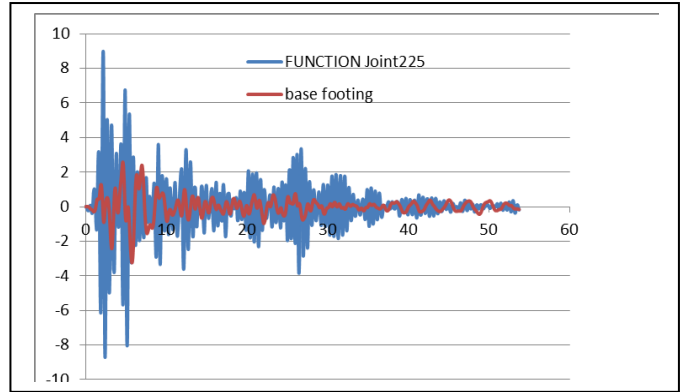
**TABLE 3 Output result for El-Centro and Northridge Earthquake**

Earthquake	Base isolator at plinth level		Base isolator at first floor level	
	Northridge	El-Centro	Northridge	El-Centro
Acceleration	6.305	3.028	5.452	2.899
Displacement	0.3219	0.1407	0.3428	0.1426

The structure analyses for above time history for soft soil condition. For the analyses structural time period has assumed 2.5sec. As result output it is found that the response of base isolated structure is predominantly lower than fixed base structure. When base isolator is shifting at plinth level and first floor level acceleration reduces significantly. A displacement has increased drastically to make the structure flexible and lower damage. Here earthquake response comparisons have plotted for fixed base and base isolators at different levels in building. The peak values for fixed and base isolators at different levels are given in table 2 and 3. Acceleration response of fixed base and base isolators at footing, plinth and first floor levels in building for Northridge and El-Centro earthquake are shown in figure 4 and 5 respectively



**Fig. 4. Acceleration response of fixed base and base isolator at different levels in building for Northridge earthquake**



**Fig. 5. Acceleration response of fixed base and base isolator at different levels in building for El-Centro earthquake**

**6. CONCLUSION**

The analysis of fixed base and base isolator at different levels three storey building is performed in this paper. An exhaustive study has been performed on the performance of base isolated structures. The behavior of building structure resting on laminated rubber bearing is compared with fixed base structure under maximum capable earthquake. An output results for acceleration and displacement are presented in Table 2 and

Table 3. Seismic base isolation can reduce the seismic effects and therefore floor accelerations are reduced by lengthening the natural period of vibration of a structure via use of rubber isolators between the column and the foundation and above the beam for plinth and first floor level. However in case the deformation capacity of the isolators exceeded, isolator may rupture or buckle. Therefore it is vitally important to accurately estimate the peak base displacements in case of major earthquakes, particularly if the base isolated building is likely to be stuck by near- fault earthquakes. Based on the analysis carried out, it is concluded that seismic base isolation is a successful technique that can be used in earthquake resistant design. According to analysis study, the conclusions are the peak top floor acceleration is reduced from 14.02 to 7.163 for footing level, 7.163 to 6.305 for plinth level, 6.305 to 5.452 for first floor level in case of Northridge earthquake while 8.984 to 3.243 for footing level, 3.243 to 3.028 for plinth level, 3.028 to 2.899 for first floor level in case of El-Centro earthquake, from which it is possible to arrive at optimum location of the isolator so as to get the maximum benefit of base isolation.

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