PERFORMANCE OF RCC BUILDING UNDER DIFFERENT SEISMIC ISOLATION LEVELS

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Abstract : A large proportion of world's population lives in regions of seismic hazards, at risk from earthquakes of varying severity and frequency of occurrence. To reduce the damage caused due to earthquake on building, seismic isolation is one of the best technical advantages used now days. Mid-storey isolation is a new technique of seismic isolation which was invented for strengthening of old weak structures to withstand seismic activities. The method is preferred over other strengthening methods due to cost effectiveness and efficiency of results. The purpose of this study is to find the performance of a 15 storey RCC building in terms of storey displacement, storey drift, storey acceleration, storey shear, base shear and time period when seismic isolators are installed at two different levels. One isolator would be at the base and the second isolator would be variable with 3 storey interval and the optimum position for using the second isolator would be found out in the study.

In the present study two similar 15 storey RCC buildings have been analyzed using response spectrum method i.e. linear static analysis. One of the buildings is fixed at its base and the other one is installed with a lead rubber isolator at its base. The analysis is carried out using ETABS 16.2.1 a product of Computers and Structures, Inc.

***IndexTerms* - storey isolation, base isolation, response spectrum analysis, time period, storey displacement, storey acceleration**.

I. Introduction

Seismic isolation is the technique used for minimizing the adverse effects of seismic activity on the structure. Most commonly used seismic isolation technique is the base isolation. Base isolation is decoupling or separating or as the name says, isolating the superstructure from its foundation by means of isolation devices. All the types of isolators work on the basic principle of energy dissipation. Flexibility of isolators towards lateral movement helps dissipating seismic energy by increasing time period of structure. Lead rubber isolators have alternate thin layers of steel and rubber around a central lead core. This assembly has very high vertical stiffness and possesses low stiffness in lateral direction, which allows them to displace laterally. Hence the level just above the isolators attains maximum displacement and the storey drift reduces over the height of building. Seismic isolators provided at storey level work in the same manner and combination of base plus storey isolation could be advantageous over single level of isolation.

II. Literature Reivew

Zhou *et al.* (2004) had completed a case study on increasing the strength of the existing building by isolating an intermediate storey of a RCC building in Tokyo. It was concluded that as compared with other strengthening methods such as steel framed bracing, external cladding, energy absorbing vibration damping, base isolation; mid-storey isolation method is cheaper and effective.

Jain *et al.* (2004) found the seismic response of base isolated buildings with higher natural period ranging from 1 second to 3 seconds by increasing stiffness of superstructure, damping of superstructure and flexibility of isolation system. It was noted that increase in superstructure stiffness results in reduction of maximum roof acceleration and storey drift and increase in maximum storey shear and base slab displacement. Similarly increase in superstructure damping does not induce appreciable reduction in seismic response of structure. Increase in flexibility of isolation system effectively reduces the seismic response of structure but there is a little increase in maximum base displacement.

Zhou *et al.* (2004) performed a case study on the largest seismic isolated area in the world built over a railway station which included 50 numbers of nine storey buildings, in China. It was observed that design horizontal seismic load for super structure was decreased to$1/4^{th}$, cost saved about 7% and safety level increased 3 times for RC base isolated building over traditional anti-seismic structure. Similarly, for middle storey isolated building the horizontal load was decreased to $1/3^{rd}$ – $1/4^{th}$ and safety level increased about 4 times. Possible number of storeys above the platform could go up to 9 from 6 due to base isolation.

Phocas *et al.* (2012) conducted a parametric study on structures with multiple level storey isolation with time history method for 13 earthquakes, on a six storey RCC building. All the possible combinations starting from the single base isolated structure to all storey isolated structure has been carried out. It was seen that the fundamental time period increases as the number of isolators increases and the most optimum situation observed when isolation provided at three storey levels.

Aydin *et al.* (2012) obtained the seismic response of a 4 storey structure by altering the stiffness of isolation system from low, moderate to high. The low stiffness rubber isolators provide a better structural behavior compared to moderate or high stiffness rubber isolators. The increase in stiffness of isolator cause reduction in increment of fundamental time period, decrease in the maximum base displacement, increase in the storey drift and increase in the storey acceleration.

Shaikh *et al.* (2015) studied the effect on the performance of a 3 storey building fixed at base with isolation at three different levels, one at a time i.e. once at the foundation level then on the first storey level and then on the second storey level. It was seen that floor accelerations reduces by lengthening the natural period of vibration of a structure with the use of rubber isolators.

Donato et al. (2016) performed the seismic assessment of structure with two types of elastomeric isolation devices placed in combination with friction slider i.e. HDRB + FS and LRB + FS. They concluded that LRB isolators show a greater dissipative capacity, from 15% to 30% more compared to HDRB. It is necessary to control the higher dissipative capacity of LRB since they may also determine greater values of storey drifts. LRB isolators have stable hysteretic cycles and negligible dependence on strain history. HDRB isolators show considerable dependence on strain history.

Santhosh et al. (2017) studied seismic behaviour of G+10 RCC building with and without base isolation for different seismic zones, using seismic coefficient method as per IS1893:2002. Results obtained for relative roof displacement of a base isolated structure is less than that of fixed base structure and displacement goes on increasing as the zone changes from zone-II to zone-V.

Tsuneki *et al.* (2018) had completed a case study on middle storey isolation system of 3 buildings in Japan. The study shows that in a middle-story isolated structure, the vibration characteristics of the building are governed by the stiffness of the isolation layer, stiffness of the structure and also the degree of freedom of architectural planning can be expanded and the seismic performance increased by the adoption of a middle-story isolated structure.

III. Methodology

In the present study, 15 stories of RCC building is analysed using response spectrum method as per IS1893:2002, for zone-IV, with and without base isolation technique, using ETABS V16.2.1 and the analysis results are compared.

Input Data:

Plan dimensions: 20m x 15m (4 bays @ 5m c/c in X direction and 3 bays @ 5m c/c in Y direction)

Column dimension: 500mm x 500mm

Beam dimension: 230mm x 500mm

Floor to floor height: 3m

Effective stiffness of isolator: 1550 kN/m

Effective damping of isolator: 31%

Vertical stiffness of isolator: 1164000 kN/m

Yield strength of isolator: 106 kN

IV. Results and Disscussion

The results of analysis of 5 storey building without and with isolation is carried out by modelling the structure in ETABS are as discussed below.

Modal Time Period:

The time period of first mode of fixed building, which is translational in Y direction, is 2.74 seconds and increased to 4.065 seconds after base isolation. Second mode of vibration is translational in X direction and third mode is torsional. Table 1 shows the time periods of first 7 modes.

Table 1: Modal time period

Modes	Time period in seconds	
	Structure with Fixed Base	Structure with Base Isolated
1	2.739	4.065
2	2.66	3.997
3	2.419	3.647
4	0.893	1.206
5	0.87	1.171
6	0.794	1.053
7	0.51	0.624

Modal Mass Participation Ratio

The mass participation ratio of first mode is 79.66% increases considerably to 95.82% by providing base isolation. Table 2 shows the mass participation ratios of first 7 modes.

Table 2: Modal mass participation ratio

Modes	Structure with Fixed Base		Structure with Base Isolated	
	X	Y	X	Y
1	0	0.7966	0	0.9582
2	0.8004	0.7966	0.9619	0.9582
3	0.8004	0.7966	0.9619	0.9582
4	0.8004	0.8996	0.9619	0.9943
5	0.9005	0.8996	0.9947	0.9943
6	0.9005	0.8996	0.9947	0.9943
7	0.9005	0.9354	0.9947	0.9982

Storey Displacement

Displacement of fixed building in X direction increases from zero to 119 mm as shown in figure 1; while for base isolated building, 1st storey displaces to 80 mm and increase in displacement with height goes upto 162 mm at top. Thus relative roof displacement is reduced by 37mm as shown in figure 2.

Storey Drift

As shown in figure 3 storey drift attains a peak value at 1st storey level for base isolated building due to greater displacement of isolated first story. The drift values are lesser than fixed building over the height.

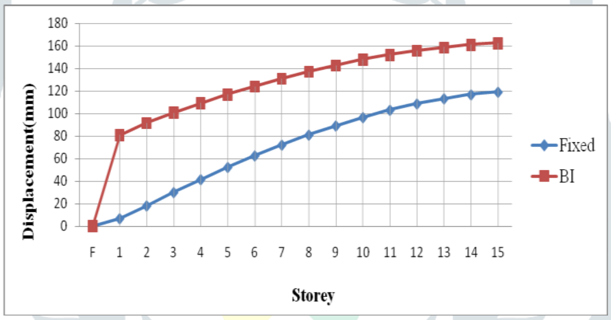

Figure 1 : Story Displacement

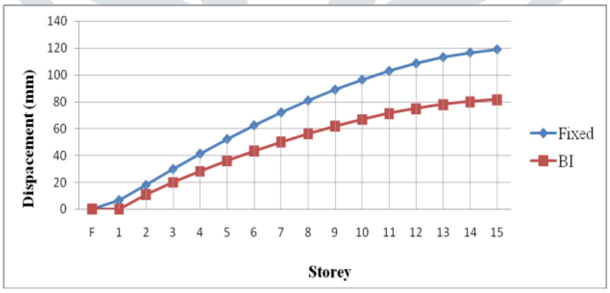

Figure 2: Relative Storey Displacement

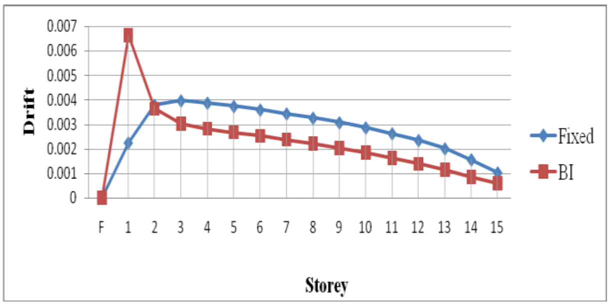

Figure 3: Storey Drift

Storey Acceleration

The acceleration for fixed building varies with height with top storey acceleration being 1237 mm/s^2, while base isolated building has nearly constant acceleration over the height with top storey acceleration being 534 mm/s^2 as shown in figure 3.

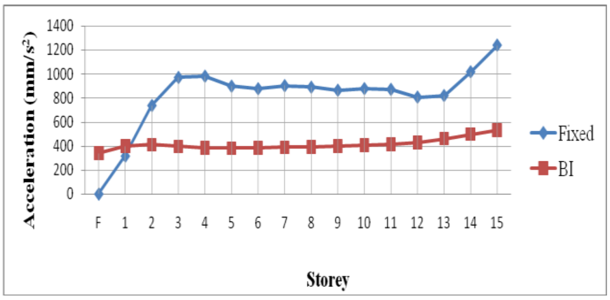

Figure 3: Storey Acceleration

Storey Shear

Base shear of fixed building observed is 2687kN which reduces over the height; whereas the base shear for base isolated building observed is 1946kN which reduces almost linearly over the height as shown in figure 4.

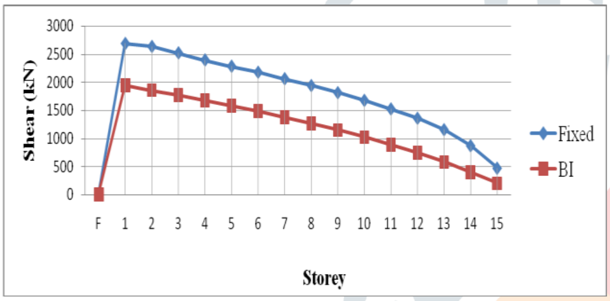

Figure 4: Storey Shear

V. CONCLUSIONS

The response spectrum analysis of a 15 storey RCC building with and without base isolation is carried out in the present study. Following are the conclusions;

1. Fundamental modal period of building without base isolation is observed 2.74sec which increases to 4.065sec with the use of base isolator.
2. Modal participation ratio of first mode increases from 79.66% to 95.82% by using base isolation.
3. Relative top storey displacement reduced by 37% with use of base isolator as compare to fixed base structure.
4. Storey drifts was reduced by an average of 32% with the use of base isolation when compared with fixed base building.
5. Storey accelerations is almost constant through the height of building when base isolation was used, as compared to fixed base building where accelerations were variable over the height. Top storey acceleration was reduced by 56% using base isolation.
6. Base shear reduced by 27.5% with use of base isolator.

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