

Comparative Seismic Analysis of Base Isolated and Fixed Based RC Frame Building

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Abstract— Base isolation (BI) is a technique that has been used around the world to protect the building structures from the damaging effects of earthquake. The installation of isolator in building at base level significantly increases the time period of the structure, which means it reduces the possibility of resonance of the structure giving rise to better seismic performance of the building. The study is performed to compare the effectiveness of base isolation over the fixed based building and fixed based building with shear wall. For this study, 10 storied R.C frame building is considered and Time History analysis is carried out for Bhuj earthquake using ETABS 2015 software. The Lead Rubber Bearing (LRB) is designed as per UBC 97 code and the same was used for analysis of base isolation system. The results obtained from the analysis were time period, deflection and base shear. The models selected for analysis were fixed based building, fixed based building with shear wall and base isolated building.

Key words: Base isolation, time history analysis, shear wall, Bhuj earthquake, ETABS

I. INTRODUCTION

The Indian subcontinent has a history of devastating earthquakes. The shaking memories of high intensity earthquakes of Bhuj and lathur are still alive in our minds. Even now there are frequent occurrences of earthquakes in the Kashmir and Himalayan region. The major reason for the high frequency and intensity of the earthquakes is that the Indian plate is driving into Asia at a rate of approximately 47 mm/year. Geographical data of India shows that almost 54% of the land is susceptible to earthquakes. A World Bank & United Nations report shows estimates that around 200 million city occupiers in India will be exposed to storms and earthquakes by 2050.

Several seismic construction designs and technologies have been developed over the years in efforts to reduce the effect of earthquakes on structures, bridges and potentially susceptible contents. Seismic isolation is relatively recent and growing technology of this kind [2].

A. Base Isolation

Base isolation, also known as seismic base isolation or base isolation system 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 protecting a building or non-building structure's integrity.

Base isolation system is the frequently adopted earthquake resistance system. It reduces the effect of ground motion and thus leads to nullify the effect of earthquake to on the structure. Base isolation has become popular in last couple of decades in its implementations in buildings and

bridges. Base isolation has become a traditional concept for structural design of buildings and bridges in high risk areas. The isolation system decouples the structure from the horizontal components of the ground motion and reduces the possibility of resonance. This decoupling is achieved by increasing the flexibility of the system, together with appropriate damping by providing isolator at the basement level of the structure [9].

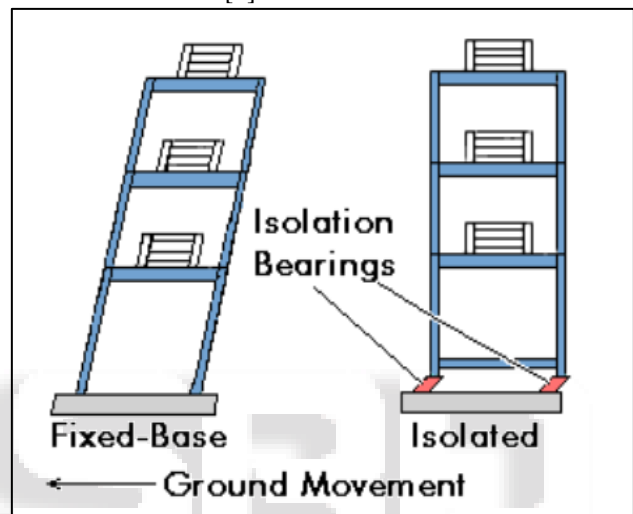


Fig.1

The principle in base isolation,

- To provide horizontal flexibility as well as vertically stiffness to the building.
- To lengthening the natural period of the building.
- Damping in the Isolation system reduces the displacement.
- It also reduces in the acceleration of the story.
- Base isolation system should contain following:
 - An elastic mount to add enough vibration periods to the structure to lower down the forces in the structure over.
 - An energy dissipater or damper to ease the deflection taking place between the structure and the ground.
 - Introducing the stiffness against the seismic actions and wind loads.

Base isolation is required if any circumstances arise of the following:-

- Need to increase the safety of the structure.
- Low lateral seismic forces needed.
- Any existing building is not capable to withstand any earthquake.
- Withstand small earthquakes without any damage.
- Structure will not collapse in high level earthquake but some structural and non-structural damage will occur.

II. OBJECTIVES OF THE WORK

To compare the response of the building such as time period, base shear and joint displacements for 10 storied RC buildings with and without base isolation in ETABS by considering the time history analysis using Bhuj earthquake data.

III. METHODOLOGY

A. Modelling and analysis

This study includes modelling and analysis of the models using standard ETABS software version 2015. Vertical reaction of ground storey inner column is calculated by service loads. Time history analysis are performed on models using Bhuj earthquake data.

B. Models considered for analysis

- 1) Fixed based building.
- 2) Fixed based building with shear wall.
- 3) Base isolated building

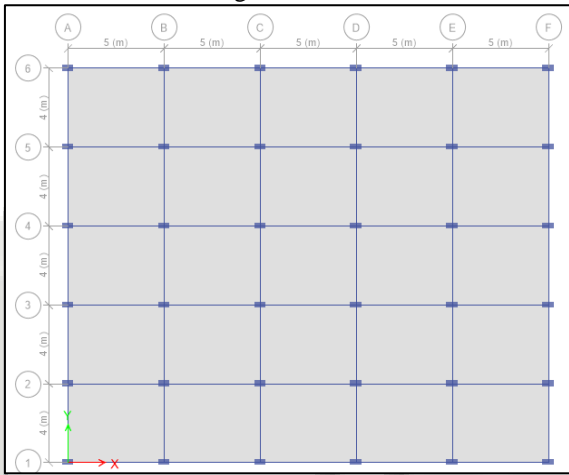


Fig. 2: Plan view of the model

C. Structural specifications

No of storey	G+9
Spacing of frames in X direction	5.0m
Spacing of frames in Y direction	4.0m
Size of beam	300 x 500mm
Size of column	400 x 600mm
Storey height	3.2m
Thickness of slab	150mm
Thickness of wall	230mm
Thickness of parapet wall	150mm
Height of parapet wall	1.2m
Thickness of Shear wall	200mm

Table 1: Member Properties

Grade of Concrete	M30
Grade of Steel	Fe415
Density of Brick masonry	20 kN/m ²

Table 2: Material Properties

Live load on roof	1.5 kN/m ²
Live load on floor	5 kN/m ²
Floor finish	1 kN/m ²

Table 3: Load Intensities

Type of Soil	Meduim
Earth quake zone	V
Zone factor, Z	0.36

Importance factor, I	1.5
Response reduction factor, R	5

Table 4: Design Spectrum

D. Properties of LRB used for analysis

The maximum gravity service load acting on the interior column at the base of structure is 5128.34kN which is considered in the design. Lead Rubber Bearing has been designed as per specified in UBC 97, simplified design procedure given in [6] is adopted.

Modulus of Elasticity, E	4.45 x 10 ³ kN/m ²
Shear Modulus, G	1.06 x 10 ³ kN/m ²
Material constant, k	0.57
Design shear strain, γ_{max}	50%
Effective damping ratio, ξ_{eff}	10%
Minimum elongation at break, ϵ_b	500%
Yield strength of lead core, f_{py}	8.82 x 10 ³ kN/m ²
Allowable normal stress, σ_c	7.84 x 10 ³ kN/m ²
Yield strength of steel plates, F_y	2.74 x 10 ⁵ kN/m ²
Yield stress of steel plates, F_s	1.65 x 10 ⁵ kN/m ²

Table 5: Standard Material Properties of Isolator

Eff. Vertical Stiffness, K_v	544881.79 kN/m
Eff. Horizontal Stiffness, K_h	1513.676 kN/m
Pre Yield Stiffness, K_u	10872.53 kN/m
Post Yield Stiffness Ratio, $\frac{K_d}{K_u}$	0.1
Yield Force of Lead Plug, Q	59.94 kN

Table 6: Isolator Input Parameters for Etabs

IV. RESULTS

A. Storey Forces and Base Shear

The storey forces are obtained from time history analysis for 10 storey building models, along both X and Y directions are listed in the tables 7 to 8 respectively.

Storey No.	Fixed Base (kN)	Fixed Base with SW (kN)	Base Isolated (kN)
1	5898.9259	14148.2867	2579.861
2	5881.2906	14009.371	2336.3599
3	5810.7497	13721.8094	2180.5145
4	5652.0327	13141.5001	2039.9373
5	5369.8691	12142.389	1865.5279
6	4928.9884	10766.9808	1614.3898
7	4303.2665	9280.031	1293.0585
8	3859.227	7408.2756	979.3469
9	2984.6598	4927.2577	628.0544
10	1217.5036	1810.9514	220.5768

Table 7: Storey Forces In X Direction

Storey No.	Fixed Base (kN)	Fixed Base with SW (kN)	Base Isolated (kN)
1	5583.7478	12276.6318	2233.8754
2	5356.3764	11926.9725	2151.5346
3	5292.1313	11203.2119	2060.1629
4	5149.4734	10269.3667	2036.6976
5	5145.5245	9186.4725	1970.0408
6	4815.7885	8455.884	1786.2645
7	4338.0048	7425.9746	1509.5733
8	3517.8034	6013.9709	1194.5683
9	2519.0368	4398.4	791.5832
10	1018.2206	1760.7396	282.9306

Table 8: Storey Forces in Y Direction

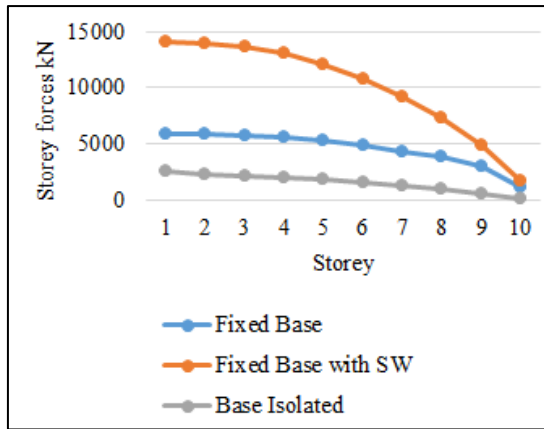


Fig. 3: Storey forces vs Storey in X direction

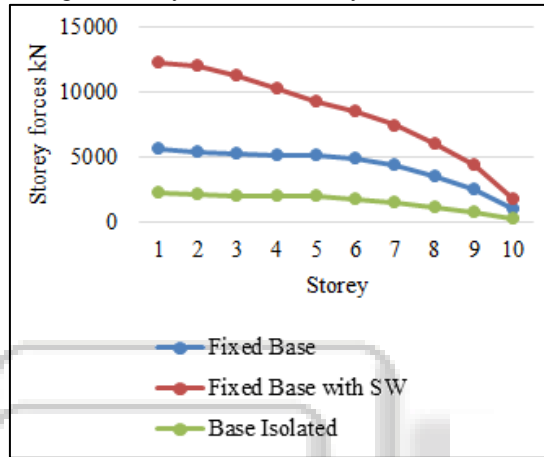


Fig. 4: Storey forces vs Storey in Y direction

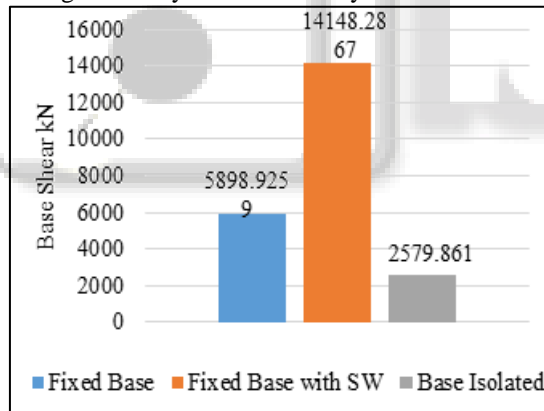


Fig. 5: Base shear in X direction

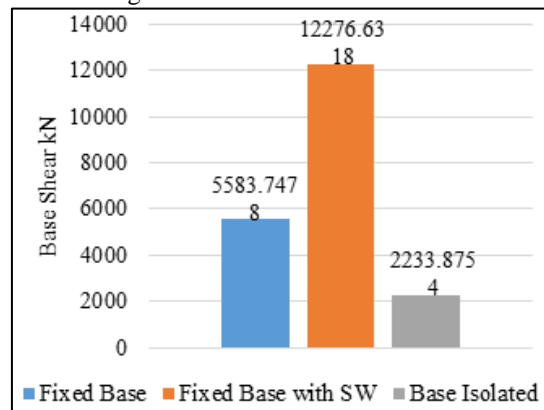


Fig. 6: Base shear in Y direction

B. Storey Displacement

The storey displacements obtained from time history analysis for 10 storey building models, along both X and Y directions are listed in the tables 9 and 10.

Storey No.	Fixed Base (mm)	Fixed Base with SW (mm)	Base Isolated (mm)
Base	0	0	17.351
1	6.527	2.818	20.73
2	17.478	8.019	24.363
3	29.192	14.819	26.255
4	40.796	22.701	29.369
5	51.891	31.19	31.442
6	62.116	39.882	33.537
7	71.063	48.471	36.156
8	78.277	56.73	39.745
9	83.31	64.537	42.251
10	86.063	71.681	43.703

Table 9: Storey Displacement In X Direction

Storey No.	Fixed Base (mm)	Fixed Base with SW (mm)	Base Isolated (mm)
Base	0	0	13.886
1	8.701	2.637	15.996
2	21.148	7.379	20.29
3	33.913	13.643	24.25
4	46.47	21.038	27.567
5	58.494	29.108	30.382
6	69.619	37.449	33.808
7	79.407	45.717	36.629
8	87.355	53.654	40.223
9	92.912	61.092	41.775
10	95.796	67.883	42.571

Table 10: Storey Displacement In Y Direction

As per 11.3.3 of Structural Analysis of Regular Multi-Storey Buildings the recommended value for the maximum deflection of the building is [10],

$$V. V_{MAX} = \frac{H}{500}$$

$$VI. (1)$$

Where, H = total height of the building = $\frac{32000}{500}$

$$\therefore V_{max} = 64 \text{ mm}$$

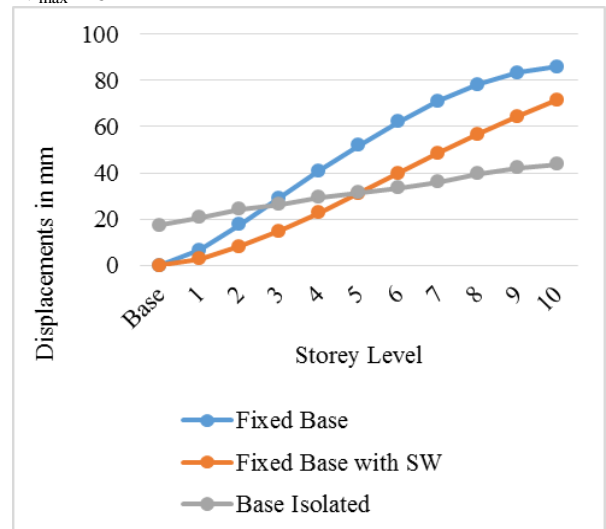


Fig. 7: Displacements vs Storey level in X direction

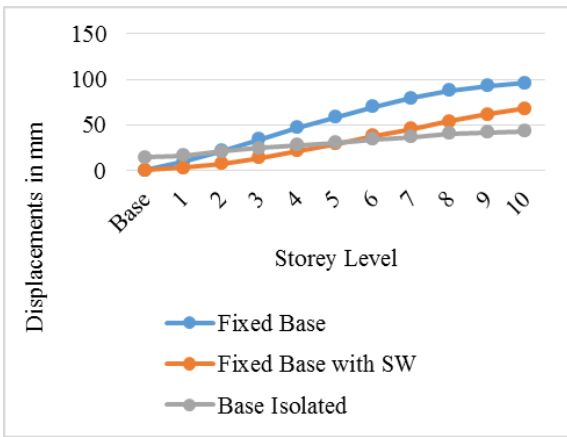


Fig. 8: Displacements vs Storey level in Y direction

A. Time Period

The time period obtained from time history analysis for 10 storey building models are shown in below Fig. ures.

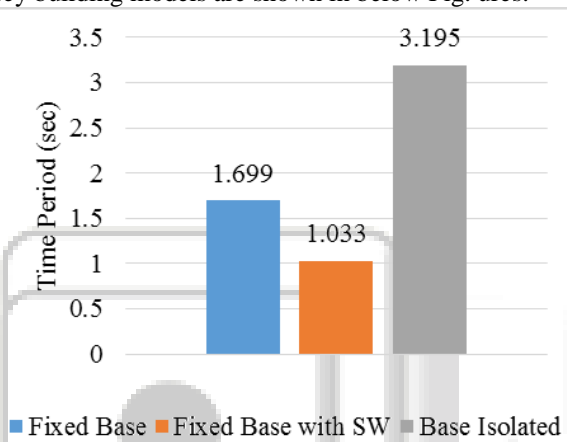


Fig. 9: Time period

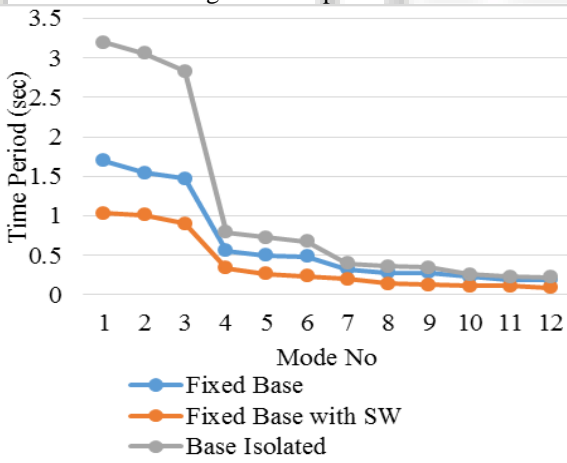


Fig. 10: Time Period vs Mode No

VII. OBSERVATIONS AND CONCLUSIONS

Following are the observations made from the present study,

- The base shear in x and y direction gets reduced by 56% and 60% respectively when base isolation is provided as compare to fixed based building.
- The base shear in x and y direction gets reduced by 82.8% and 81.8% respectively for base isolated building as compare to fixed based building with shear wall.

- As result of the increased flexibility of the base isolated system, time period of the structure is also increases as compare to other two models.
- The time period decreases and base shear increases for fixed based building with shear wall due to rigidity caused by shear wall.
- The maximum displacement in x and y direction of the top storey for base isolated building is reduced by 49.2% and 55.6% respectively as compare to the maximum displacement of fixed based building.
- The maximum displacement in x and y direction of the top storey for base isolated building is reduced by 39% and 37.3% respectively as compare to the maximum displacement of fixed based building.

The following are the conclusions from the results of the present study on use of base isolation systems in buildings.

- The base isolated building is having high efficiency in decreasing the base shear compare to fixed based building and fixed based building with shear wall.
- From this study it shows that, the building gives better performance by the use of isolators at the base of the building as compared to fixed based building or fixed based building with shear wall at higher seismic prone area.
- The maximum lateral storey deflection for base isolated building is less than the recommended value, whereas the maximum lateral storey deflection of fixed based building and fixed based building with shear wall goes beyond recommended value.
- Since the base shear and the deflection of the base isolated building is much less, the cross section of beams and columns can be reduced in order to achieve economy.

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