Parametric Comparison of Structures with and Without Base Isolation

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Abstract

The use of different techniques in the seismic prone regions to minimize the effect of seismic forces is not new. The most common technique being the use of shear walls to provide enough stiffness so as to decrease the sway of the building. The modern structures however may not be considered fully economical if the cost of the shear walls is exceeding a certain limit. To satisfy this need many innovative methods are deployed among which the use of base isolators is gaining popularity in designers. The concept of base isolator is rather simple that the support is given a degree of freedom to move independent of the superstructure because of which the base acts like a damper for the seismic or wind excitations and the superstructure remains lesser affected. Base isolators are used in many countries around the world to prevent any damage to the property or the occupants during and after the course of an earthquake. In the following discourse a comparison of a traditional RCC frame building with fixed supports to that of a building with rubber base isolator is done to check for the changes in the crucial parameters and at the end a comparison is made.

Keywords: *Lead Rubber base isolator, Base isolator, seismic force*

Introduction: During an earthquake tremendous amount of energy is released in the form of shaking of earth and the resultant is the vigorous shaking of the objects and the structures above the ground[1]. This causes discomfort if the intensity is very low but if the intensity is high the effects can be devastating sometimes resulting in the collapse of the structure causing loss of lives[2]. Base isolation is a technique used to nullify the effect or at the least decrease the effect of the earthquake forces[3]. In this method the footings are constructed with rubber laminated isolators that slide with a particular friction in the direction of the force applied by the earthquake force. The fundamental concept behind the base isolation is to distinguish the base of the structure from its superstructure so that it can move independently without disturbing the inertia of the structure[4]. The Lead Rubber base isolator is one of the most trusted isolators among many other viscoelastic isolators due to its high stiffness and strength[5]. LRB is also the easiest to acquire in the Indian market and so the same is used in the present study.

Methodology: In the study two structures are created using the finite element software ETABS. The two structures are identical except for the change in the footing. One being with the base isolator and the other with the conventional RCC fixed footing. The structures are modelled using the codal provisions of the Indian standard code of practice for RCC design. The structures are situated in the most earthquake prone zone 5 with hard soil conditions. The material used were M25 concrete and Fe 415 steel along with slab thickness of 125mm. The parameters considered for the comparison are the critical aspects of the design data to ensure the safety of the habitants of the structure like storey drift, storey shear and storey displacement. The loadings of the structures were considered as the average loadings which are frequently used in the construction industry to maximize the economy of the structure and also to provide adequate safety without cutting corners. The site conditions are particularly taken the most critical in the zone 5 to simulate the extreme effects that the earthquake excitations the structure can experience during its serviceable age. The other design parameters such as the loadings and the storey data is given in the table 1 below.

Table 1: Parametric data for RCC as well as base Isolator models

Parameter considered	**Value**
Live load	2.00 kN/Sq.m
Dead load	2.00 kN/Sq.m
Floor finish	1.50 kN/Sq.m
EQ Zone	5
Soil type	Hard soil
Importance factor	1.2
Floor height	3 m
Slab thickness	125 mm
Response reduction factor	5.0
Grade of steel	Fe415
Grade of concrete	M30
IS Codes Referred	
Steel Building Code	IS 800:2007
Earthquake Design Code	IS 1893(Part 1):2016
Live load Calculated	IS875:1987 Part 1
Dead Load Calculated	IS875:1987 Part 2
Wind Load Calculated	IS875:2015 Part 3

Table 2: Beam and Column sections consideration for beams

Particulars	RCC model with only Fixed base conventional footing	RCC model with base Isolated footing
Column sizes Considered		
Foundation to 5th floor	(230X500) mm	(230X500) mm
6th floor to 10th floor	(230X450) mm	(230X450) mm
11th floor to 16th floor	(230X700) mm	(230X400) mm
Beam sizes Considered		
Foundation to 5th floor	(230X380) mm	(230X380) mm
6th floor to 10th floor	(230X350) mm	(230X350) mm
11th floor to 16th floor	(230X300) mm	(230X300) mm

Base Isolator used: The base isolators are available in various types in the market depending upon the requirement the engineers can obtain any desired flexibility or stiffness. The isolator used in this study is the Lead rubber base isolator which is manufactured by stacking lead pates with rubber plates. The thickness, material properties and the overall surface properties are closely calculated to obtain the ordered properties in the factory. Lead rubber base isolator has been tested for its serviceability and strength criteria in the recent structures constructed with the same technique in Taiwan and Hongkong. Lead Rubber isolator also requires less maintenance as compared to other isolators.

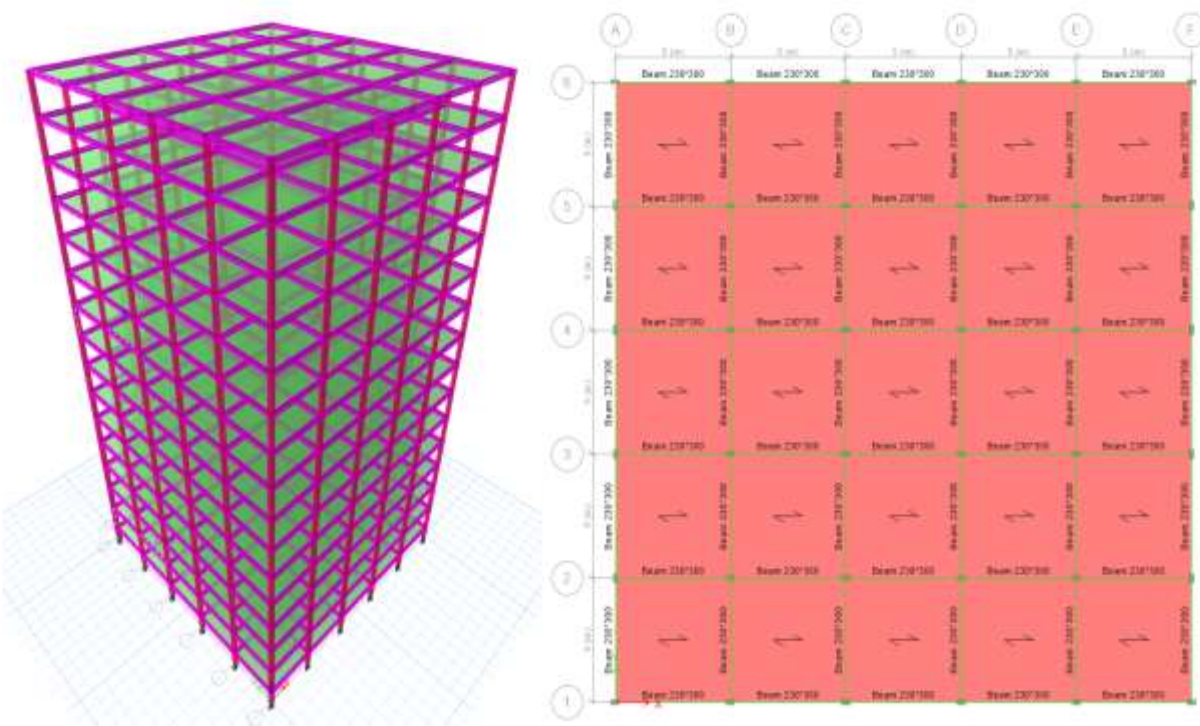

Figure1: 3-d and plan view of the structure with and without LRB isolator

Results and Discussion: The structures with and without the base isolator are compared on the basis of the critical parameters such as the storey displacement, storey shear and storey displacement along with the modal time period. After careful analysis and study of the results the following conclusions were drawn.

1. Storey drift: The inter storey drift is one of the major concerns while designing any structure specially when the structure location is in an earthquake prone area. Storey drift is the comparative measure so the dimensions cancel out. Storey drift is generally neglected when the earthquake forces are negligible but its is highly recommended to check for storey drifts in critical structures. Storey drift comparison between the structures is shown in table 2 below.

Table 2: Maximum storey drifts for Conventional and LRB models

Parameters	Conventional Fixed footing model	LRB Model
Maximum Drift for static X	0.001578	0.001571
Maximum Drift for static Y	0.001493	0.001511
Maximum Drift for dynamic X	0.001034	0.000973
Maximum Drift for dynamic Y	0.000986	0.001007

2. Base Shear: Base shear is the amount of force calculated at the base of the structure when there are any lateral forces like wind or earthquake. Generally, structures are checked for at least one dominant force at the site where it is situated and designed accordingly. Base shear comparison for structures with and without LRB is given in table3.

Table 3: Maximum Base shear for Conventional and LRB models

Parameters	Conventional Fixed footing model	LRB model
Base shear for static in X	3134.07 kN	2999.6 kN
Base shear for static in Y	3354.70 kN	3103.8 kN
Base shear for dynamic in X	3631.60 kN	3409.9 kN
Base shear for dynamic in Y	3712.32 kN	3323.1 kN

3. Storey Displacement: Storey displacement is the measure of the movement of the floors of the structure with respect to the base. The individual floors are displaced during the earthquake excitations and the distance is measured in millimeters. The storey displacement comparison is shown in table 4.

Table 4: Maximum Storey Displacement for Conventional and LRB models

Parameters	Conventional Fixed footing model	LRB model
Max Displacement for static X	112.76 mm	96.95 mm
Max Displacement for static Y	107.46 mm	93.51 mm
Max Displacement for dynamic X	71.05 mm	58.07 mm
Max Displacement for dynamic Y	68.87 mm	60.11 mm

4. Time Period: The modal time period is the measure of the natural oscillation time taken by the structure. The parameter is closely monitored and becomes a priority as the height of the structure increases. The comparison of the modal time period is given in table 4 below.

Table 4: Maximum Storey Displacement for Conventional and LRB models

Modal Time Period	Conventional Fixed footing model	LRB model
Mode 1	3.330 seconds	3.823 seconds
Mode 2	2.920 seconds	3.474 seconds
Mode 3	2.636 seconds	3134 seconds

Conclusion: The structures with and without the base isolator are compared on the basis of the critical parameters such as the storey displacement, storey shear and storey displacement along with the modal time period. After careful analysis and study of the results the following conclusions were drawn.

1. This approach tries to reduce the stiffness of the system so that the fundamental period of oscillation of the system reduced creating a lesser displacement of the subsequent floors.

2. The storey drift of the structure with the base isolator is lesser than the structure with the fixed base.

3. The storey displacements were found to be lesser to a large margin in the structure with Base isolator.

4. The base shear experienced by the structure with base isolator was also lesser in comparison to the traditional fixed base structure.

As each structure is different due to the different site conditions and the material properties, the results may vary slightly or to a greater value depending upon the circumstances but the Base isolation technique if applied is expected to outperform the traditional structure in most of the situations.

References

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