Seismic Analysis of High-Rise Building Having lateral Load Resisting Elements with and without base isolation

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ABSTRACT

In present work linear dynamic analysis (i.e. Response spectrum) of high-rise building is done and base isolation is analyzed with lateral force resisting elements like shear wall and bracing, effect of all these structural components is calculated and analyzed on high rise structure having height G+30, G+35 & G+40. Structure is located in Earthquake Zone IV. Analysis is done with the help of ETABS 19 software. Base isolation bifurcates the structure from foundation so the structure remains unharmed from shocks and motion at the time of seismic action. Base isolation is broadly used as a load resisting system which is provided to strengthen high-rise buildings. But literature survey of base isolation shows that Lead Rubber Base Isolation is proved to be an optimal solution. With the increase in urbanization use of multi stories building is now in trending because of its high utility in commercial as well as residential. In northern part of India, maximum places are susceptible to earthquakes so that no damage to the life takes places. One among various methods of earthquake resistant design is the use of Lead Rubber Base Isolation. Various studies were carried out to check the behavior of different parameters like time period, drift, Storey displacement and overturning moment etc. with various types of base isolation. Use of LRB isolation system for high rise buildings was suggested. In the present study lead rubber bearing is used for base isolation with structure having shear wall and bracings. G+30, G+35 and G+40 storey structure are analyzed. Static, lineardynamic (response spectrum) is performed to study the behavior of the building with lead rubber base isolation system. ETABS v2019 is used to perform the analysis and design. Comparison of fixed base building with LRB is shown and suitability concerns is provided. It was observed from the study that Lead Rubber Base Isolation is more effective for earthquake prone zones.

I. INTRODUCTION

Earthquake is a natural earth movement that causes calamity and damages to the structures. Seismic activity occurs in the earth's crust, forming waves. These waves transmit to structures through foundation. Thus due to this earthmovements, inertia force is invoked in structure resulting in damaging the whole or part of structure. On the other hand, earthquakes provide architects and engineers with anumber of important design criteria which are unknown to the normal design process. Engineers can employ ductility to generate more displacement on a structure than the normally permissible elastic limit. The elastic limit refers to the maximum deformation of a structure before it reverts to its original shape. Cracks will develop in the structure if the building deforms more than its elastic limit. If the structure is in or near a seismic zone, the risk of an earthquake damage is quite high and unpredictable. In order to save lives and to minimize the damage structural engineers are required who can help in doing so. Base isolation is the recent development for seismic resistant design, this may not totally control the ground movement but helps in minimizing the impact of ground movement. By extending the time of vibration of the structure, base isolation helps to reduce earthquake forces. Also the structural response accelerations are less than the ground acceleration because of base isolation. It helps in limiting the effects and aftershocks of earthquake and that's why it is widely accepted in the world.
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II. OBJECTIVE
In this thesis 3 cases (G+30, G+35 & G+40) are considered in each case 4 combinations are formed i.e. shear wall + fixed base, shear wall + bracing + fixed base, and in above two case fixed base is replaced by LRB base. Dynamic analysis (Response Spectrum method) is done using CSI ETBASv19 software.

The objectives of this thesis are:
1. To determine the effect of base isolation on time period, base shear, overturning moment, Storey displacement, Storey drift.
2. To determine the behavior of Fixed base vs LRB base in Response Spectrum analysis.
3. To determine the seismic performance of LRB base as compared to Fixed structure.
4. To compare the result for LRB and Fixed base in G+30, G+35 & G+40 storey.

III. MODELLING AND ANALYSIS
To study seismic behavior and performance of multi-storied building, three configurations are used, i.e. 30-storied, 35-storied and 40-storeied building. Each configuration is further divided into 4 cases on basis of variation of base and bracing:

1. Frame with shear wall and fixed base
2. Frame with shear wall, bracing and fixed base
3. Frame with shear wall and LRB base
4. Frame with shear wall, bracing with LRB base

To study the behavior, parameters selected are storey drift, storey displacement and storey shear.

Table 3.1 Plan Dimensions

| SNO | Particulars         | Dimension/Value |
|-----|---------------------|-----------------|
| 1   | Plandimension       | 25 x 25 m       |
| 2   | Height of the storey| 3 m             |
| 3   | Height of parapet   | 1.2 m           |
| 4   | Thickness of slab   | 180 mm          |
### Table 3.2: Detail of Lateral Load Resisting Elements

| Members          | Size of Member (in mm) |
|------------------|------------------------|
| Column (M 30)    | 1000*1000              |
| Beam (M 30)      | 300*500                |
| Bracing (M 30)   | 300*500                |

#### 3.1.1 Design Data for LRB

For LRBG+30 For load of 23500 KN

| Parameter                          | Value                          |
|------------------------------------|--------------------------------|
| Rotational Inertia                 | 2.222146677 kN/m               |
| For U1 Effective Stiffness         | 35514478.63 kN/m               |
| For U2 & U3 Effective Stiffness    | 35514.4786 kN-m                |
| For U2 & U3 Effective Damping      | 0.15                           |
| For U2 & U3 Distance from End-J    | 0.00490 m                      |
| For U2 & U3 Stiffness              | 271465.7674 kN/m               |
| For U2 & U3 Yield Strength         | 1330.778648 kN                 |

For LRBG+30 For load of 38400 KN

| Parameter                          | Value                          |
|------------------------------------|--------------------------------|
| Rotational Inertia                 | 2.637942354 kN/m               |
| For U1 Effective Stiffness         | 38633313.86 kN/m               |
| For U2 & U3 Effective Stiffness    | 38633.3139 kN-m                |
| For U2 & U3 Effective Damping      | 0.15                           |
ForU2 &U3 Distance from End-J
0.00490 m

ForU2 &U3 Stiffness
295305.5374 kN/m

ForU2 &U3 Yield Strength
1447.645895 kN

For LRB of G+40 load of 41500 KN

Table 3.4 Design Data for LRB for lateral load of 41500 KN

| Rotation Inertia | 3.089726619 kN/m |
|------------------|------------------|
| For U1 Effective Stiffness | 41752149.1 kN/m |
| For U2 & U3 Effective Stiffness | 41752.1491 kN/m |
| For U2 & U3 Effective Damping | 0.15 |
| For U2 & U3 Distance from End-J | 0.00490 m |
| For U2 & U3 Stiffness | 319145.3073 kN/m |
| For U2 & U3 Yield Strength | 1564.513141 kN |

IV. RESULTS AND DISCUSSION

4.1 TIMEPERIOD

According to IS regulations, the overall height of the building and the base dimension of the building are related by a time period formula. The design of earthquake-resistant constructions is heavily influenced by that. According to the IS standards, the fundamental period of vibration is calculated using the building’s overall height or the number of storeys.

Fig. 4.1 Time period of all model with fixed base and base isolation
Time period for G+30 storey building in case of model having shear wall + fixed base is 5.12 and in case of modal with shear wall + bracing + fixed base is 4.34 while time period is observed to decrease in modal with shear wall + isolation to 5.9392 & in modal with shear wall + bracing + isolation is 5.7856.

Time period for G+35 storey building in case of model having shear wall + fixed base is 5.00305 and in case of modal with shear wall + bracing + fixed base is 4.495306 while time period is observed to decrease in modal with shear wall + isolation to 5.798944 & in modal with shear wall + bracing + isolation is 5.304461.

Time period for G+40 storey building in case of model having shear wall + fixed base is 5.876 and in case of modal with shear wall + bracing + fixed base is 4.968 while time period is observed to decrease in modal with shear wall + isolation to 5.00305 & in modal with shear wall + bracing + isolation is 6.7574.

The model time period of LRB base as compared to fixed base is 5.876 and in case of modal with shear wall + isolation is 6.7574.

### 4.2 Storey Displacement

The lateral displacement of the story in relation to the base is called story displacement. Response spectrum analysis of uniform and optimized sections are performed. Storey drift is the difference of displacements between two consecutive storeys divided by the height of that storey and Storey displacement is the absolute value of displacement of the storey under action of the lateral forces. The displacement result of this analysis is shown in graph.

Max Storey displacement for G+30 storey building in case of model having shear wall + fixed base is 153.37 mm and in case of modal with shear wall + bracing + fixed base is 89.34 mm while Storey displacement is observed to increase in modal with shear wall + isolation to 173.05 mm & in modal with shear wall + bracing + isolation is 113.6 mm.

Storey displacement for G+35 storey building in case of model having shear wall + fixed base is 191.305 mm and in case of modal with shear wall + bracing + fixed base is 110.97 mm while Max storey displacement is observed to increase in modal with shear wall + isolation to 219.235 mm & in modal with shear wall + bracing + isolation is 125.51 mm.
Max storey displacement for G+40 storey building in case of modal with shear wall + fixed base is 158.954 mm while Max storey displacement is observed to increase in modal with shear wall + isolation to 304.75 mm & in modal with shear wall + bracing + isolation is 183.75 mm. The storey displacement of LRB base as compared...
to fixed base is increased, and increase in displacement is observed because base isolation makes structure more ductile, due to this ductility in the structure tends to displace.

4.3 STOREY DRIFT

The storey shear and storey drift graphs are useful when analysing the effect of lateral loading on a multi-story building due to seismic or wind loads. The storey drift ratio is defined as the storey drift divided by storey height. Storey drift is the lateral displacement between two adjacent floors. The storey drift ratio is a useful quantity that can be directly compared to the code requirements because seismic loading rules often impose limits on storey drift as a percentage of the storey height.

Storey drift for G+30 storey building in case of model having shear wall + fixed base is 0.00217 and in case of model with shear wall + bracing + fixed base is 0.00129 while storey drift is observed to increase in model with shear wall + isolation to 0.00228 while in model with shear wall + bracing + isolation is 0.00126.

Storey drift for G+35 storey building in case of model having shear wall + fixed base is 0.00234 and in case of model with shear wall + bracing + fixed base is 0.00165 while storey drift is observed to increase in model with shear wall + isolation to 0.00251 and in model with shear wall + bracing + isolation is 0.00147.

Storey drift for G+40 storey building in case of model having shear wall + fixed base is 0.00271 and in case of model with shear wall + bracing + fixed base is 0.00153 while storey drift is observed to increase in model with shear wall + isolation to 0.00273 and in model with shear wall + bracing + isolation is 0.0016.

Fig. 4.3 Storey drift vs storey height

![Fig. 4.3 Storey drift vs storey height](image-url)
4.4 BASESHEAR

The maximum expected lateral stress on the base of the structure caused to seismic activity is called base shear. It is calculated using the seismic zone, soil material, and building code lateral force equation, it is observed that as shear at the bottom of the storey is maximum and critical so the base shear of all the model with linear dynamic analysis is carried out and result obtained are plotted in below graph.

Fig. 4.4 baseshear of different models at base in KN

The Baseshear of LRB base as compared to fixed base reduces, this reduction in baseshears due to base isolation effect of earthquake forces has been reduced significantly on to the structure also it provides damping effect to the base, and reduction in base shear is as follows:

Base shear for G+30 storey building in case of model having shear wall + fixed base is 3621 and in case of modal with shear wall + bracing + fixed base is 2670 while base shear is observed to decrease in modal with shear wall + isolation to 2111.76 and in modal with shear wall + bracing + isolation is 1694.38.

Base shear for G+35 storey building in case of model having shear wall + fixed base is 4099 and in case of modal with shear wall + bracing + fixed base is 3438.25 while base shear is observed to decrease in modal with shear wall + isolation to 2516.78 and in modal with shear wall + bracing + isolation is 2253.42.

Base shear for G+40 storey building in case of model having shear wall + fixed base is 4369.81 and in case of modal with shear wall + bracing + fixed base is 4041.907 while base shear is observed to decrease in modal with shear wall + isolation to 2875.33 and in modal with shear wall + bracing + isolation is 2837.41.

4.5 OVERTURNING MOMENT

By multiplying the story shear by the distance to the centre of mass above the height in concern, the overturning moments can be calculated. As storey shear of the building increases from top to base floor overturning moment also increases from top to base.

Responses spectrum analysis of all the structures for all the models are performed. The story overturning moment result of this analysis is shown in graph.

Overturning moment for G+30 storey building in case of model having shear wall + fixed base is 141250.7 KN-m and in case of modal with shear wall + bracing + fixed base is 169218.3 KN-m while overturning moment is observed to decrease in modal with shear wall + isolation to 99412.22 KN-m and in modal with shear wall + bracing + isolation is 124273.9 KN-m.

Overturning moment for G+35 storey building in case of model having shear wall + fixed base is 225747.2 KN-m and in case of modal with shear wall + bracing + fixed base is 268639.2112 KN-m while overturning moment is observed to decrease in modal with shear wall + isolation to 141250.7 KN-m and in case of modal with shear wall + bracing + isolation is 169218.3 KN-m.
modal with shear wall + isolation to 164343.988 KN-m & in modal with shear wall + bracing + isolation is 205132.9 KN-m
Overturning moment for G+40 storey building in case of model having shear wall + fixed base is 305247.6837 KN-m and in case of modal with shear wall + bracing + fixed base is 305247.6837 KN-m while overturning moment is observed to decrease in modal with shear wall + isolation to 223441.3 KN-m & in modal with shear wall + bracing + isolation is 217014.3 KN-m.

It is observed that overturning moment is reduced in LRB case as compared to fixed base as the base shear values are reduced significantly and moment generated by the earthquake forces is observed to be reduced significantly which results in reduction of overturning moment.

Fig. 4.5 Overturning moment vs storey height
V. CONCLUSION & FUTURE SCOPE

4.3 CONCLUSION

1. The results of analyzed LRB base and fixed base for G+30, G+35 & G+40 storey are represented in this chapter. Comparing the results of FIXED and LRB base models, the results show, the LRB base structure option is better than the fixed base. LRB base structure for high-rise buildings is the best of all options, the displacement values of the floors are within the allowable limit according to the code’s limits. LRB base gives more ductility to the structure than Fixed base most suitable under the action of lateral force. Also, the performance of LRB base is good compared to Fixed base. Effect of earthquake on the structure is reduced which helps to reduce the cost of the foundation, due to less overturning moment. Base isolated structures are the best solution for tall structures in earthquake-prone zones.

2. Considering the earthquakes, due to inherent flexibility properties of lead and rubber, LRB will perform better than conventional fixed base structures.

3. After analysis of model and results are discussed in previous chapter. Some concluded points are listed below.

4.4 FUTURE SCOPE

The following conclusions are drawn from the results within the scope of this project:

1. The maximum Storey displacement of LRB base for response spectrum analysis of 30, 35 and 40 storey building in X-direction, are 10.68-16.8% times more as compared to fixed base, which suggests that building has gained some flexibility which will result in absorbing more earthquake energy.

2. The above points conclude that use of LRB isolation system in low storey structure is more suitable than high rise structure.

3. Average percentage reduction in base shear of LRB building w.r.t. fixed base buildings is 29.80% to 41.68% in 30, 35, and 40 storey building with respective lateral supporting elements, which will result in reducing steel reinforcement of the building.

4. Time period of building can be adequately increased by using LRB base compared to fixed base which will result in reducing natural frequency of the building.

5. Intermittent storey drift can be reduced and it will help in enhancing human comfort criteria of the building.

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