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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 of high-rise building is done and of 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 structure having 30,35 &40 Stories. Structure is Located in Earthquake Zone IV. Analysis is done with the help of ETABS 19 software. In base isolation we bifurcate the structure from foundation so the structure remains unharmed from shocks and motion at the time of seismic action. Base isolation is awidely used lateral load resisting system provided to strengthen such buildings but literature survey of Base isolation reveals that Lear Rubber Base isolation is proved tobe determinantal. With the increase in urbanisation 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 earthquake so the basics requirement is to build the safe structure so that no damage to the life takes places. One among various methods of earthquake resistant design is Base Isolation. Various studies were carried out to check the behaviour 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 thepresent 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 analysed. Static, linear dynamic (response spectrum) is performed to study the behaviour of building with lead rubber base isolation system. ETABSv2019 is used to perform the analysis and design. Comparison of fixed base building with LRB is shown and suitability concern 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 earthquakemovements, inertia force is invoked in structure resulting in damaging the whole or part ofstructure.

On the other hand, earthquakes provide architects and engineers with a number of importantdesign 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... So to save lives and tominimize the damage structural engineers are required who can help in doing so. Base isolation is the recent development for seismic resistant designs, 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 after effects of earthquake andthat's why it is widely accepted in the whole world as one of the most effective approaches inpast few years.

II. OBJECTIVE

In this thesis 3 cases (G+30, 35 & 40) are considered in each case 4 combination are formed i.e. shearwall+ Fixed base, shear wall+ bracing+ fixed base, and in above two case fixed base is replaced by LRBbase. Dynamic analysis (Response Spectrum method) is done using CSI ETBASv19 software.

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The objectives of this thesis are: -

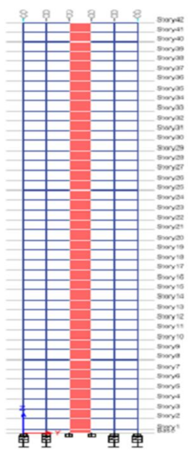
1) To determine the effect of base isolation on time period, base shear, overturning moment, storey displacement, storey drift.
2) To determine the behaviour of Fixed base vs LRB base in Response Spectrum analysis.
3) To determine the seismic performance of LRB base as compared to Fixed structure
4)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

III. MODELLING AND ANALYSIS

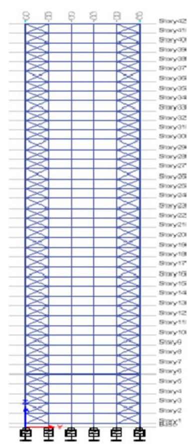
To study the seismic behaviour and performance of multi-storied building, three configurations are used, i.e. 30 storied, 35-storied and 40-storeid building. Each configuration is further divided into 4 cases on basis of variation of Base and bracing:

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

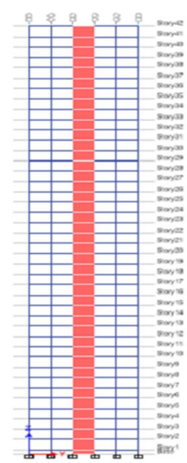
To study the behaviour, parameters selected are storey drift, storey displacement and storeyshear.



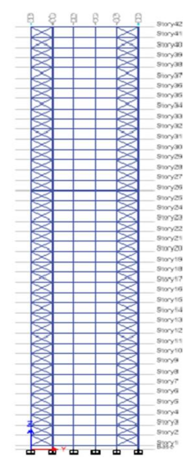
Shear wall with isolation



Shear wall,bracing with isolation



Shear wall with fixed base



Shear wall,bracing with fixed base

Table 3.1 Plan Dimensions

S NO.	Particulars	Dimension / Value
1	Plan dimension	25 x 25 m
2	Height of the storey	3m
3	Height of parapet	1.2m
4	Thickness of slab	180mm
5	Seismic zone Importance factorZone factor Damping factor	IV1.2 .24 5%
6	Floor finish Live load at all floorWall load Parapet wall Density of concreteDensity of steel Density of brick	1.0 KN/m^2 2.0KN/m^2 12.96Kn/m^2 5.96 Kn/m^{2}30Kn/m^2 7850Kg/m^{2}20Kn/m^2
7	Grade of Concrete Grade of reinforcing steelSoil condition	M 30 HYSD550 Medium

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Table 3.2 Detail of lateral load resisting elements

Members	Size of Member (in mm)
Column (M 30)	1000*1000
Beam (M30)	300*500
Bracing (M30)	300*500

A. Design Data For LRB

For LRB G+30 For load of – 23500KN

Table 3.3 Design Data For LRB for lateral load of 23500

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 LRB G+30 For load of – 38400KN

Table 3.4 Design Data For LRB for lateral load of 38400KN

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	
For U2 & U3 Distance from End-J	0.00490	m
For U2 & U3 Stiffness	295305.5374	kN/m
For U2 & U3 Yield Strength	1447.645895	kN

For LRB of G+40 – load of 41500KN

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

Rotational 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

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IV. RESULTS AND DISCUSSION

A. Time Period

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.

modal 1	5.876	4.968	6.25968	6.7574	5.00305	4.495306	5.304461	5.798944	5.12	4.34	5.7856	5.9392
modal 2	5.876	4.968	6.25968	6.7574	5.00305	4.495306	5.304461	5.798944	5.12	4.34	5.7856	5.9392
modal 3	4.593	3.346	4.21596	5.28195	2.474408	2.223288	2.62348	2.868042	3.687	2.525	4.16631	4.27692
modal 4	2.475	1.762	2.22012	2.84625	1.219409	1.095655	1.292872	1.413394	1.625	1.14	1.83625	1.885
modal 5	2.475	1.762	2.22012	2.84625	1.219409	1.095655	1.292872	1.413394	1.625	1.14	1.83625	1.885
modal 6	1.567	1.022	1.28772	1.80205	0.731306	0.657088	0.775364	0.847644	1.184	0.714	1.33792	1.37344
modal 7	1.09	0.75	0.945	1.2535	0.533862	0.479682	0.566025	0.61879	0.717	0.506	0.81021	0.83172
modal 8	1.09	0.75	0.945	1.2535	0.533862	0.479682	0.566025	0.61879	0.717	0.506	0.81021	0.83172
modal 9	0.922	0.503	0.63378	1.0603	0.368619	0.331209	0.390827	0.42726	0.691	0.361	0.78083	0.80156
modal 10	0.621	0.435	0.5481	0.71415	0.307606	0.276388	0.326138	0.356541	0.474	0.301	0.53562	0.54984
modal 11	0.613	0.435	0.5481	0.70495	0.307606	0.276388	0.326138	0.356541	0.405	0.301	0.45765	0.4698
modal 12	0.613	0.317	0.39942	0.70495	0.233882	0.210146	0.247973	0.271089	0.405	0.237	0.45765	0.4698

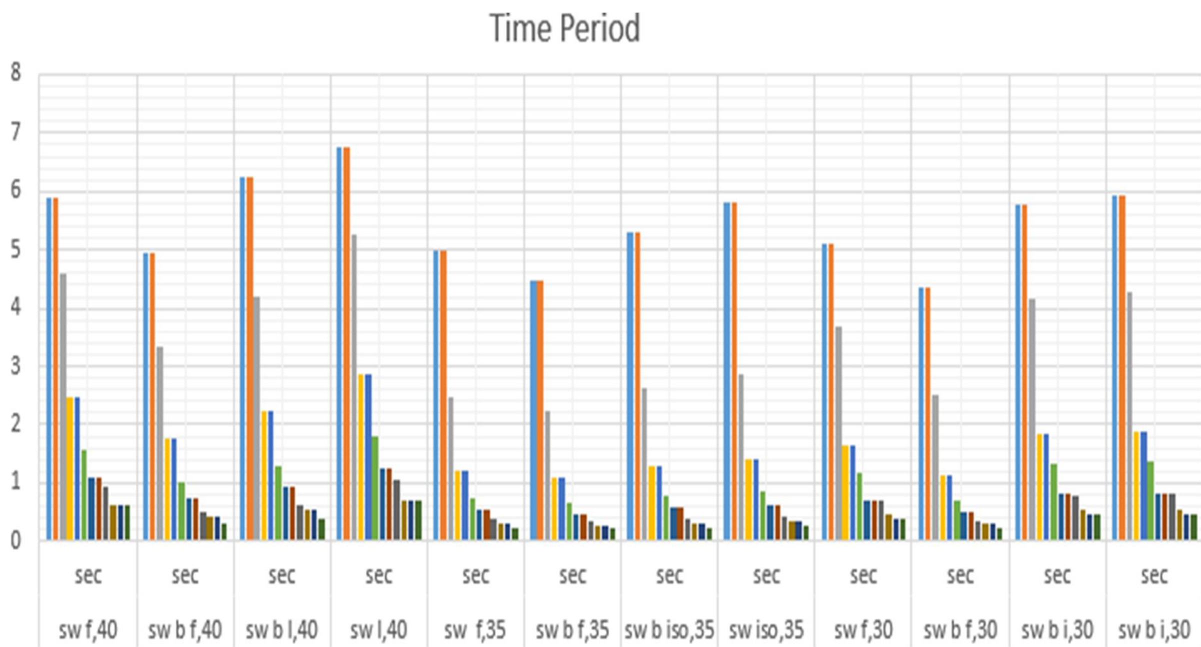

Fig. 4.1 Time period of all model with fixed base and base isolation

Time period for G+30 storey building in case of model having shear wall+ fixed base is 5.12and 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+30 storey building in case of model having shear wall+ fixed base is 5.12and 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 timeperiod is observed to decrease in modal with shear wall + isolation to 5.798944 & in modalwith 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 periodis 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 increased, this is due in base isolation, super structure is separated from sub structure so the effect of earthquake is minimized hence time period of the structure is increases and increase in time period is stated above.

B. Storey Displacement

The lateral displacement of the story in relation to the base is called story displacement. Response spectrum analysis of for uniform and optimized section are performed. Storey drift is the difference of displacements between two consecutive storeys divided by the height of that story and Story displacement is the absolute value of displacement of the storey under actionof 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 89.34mm 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.

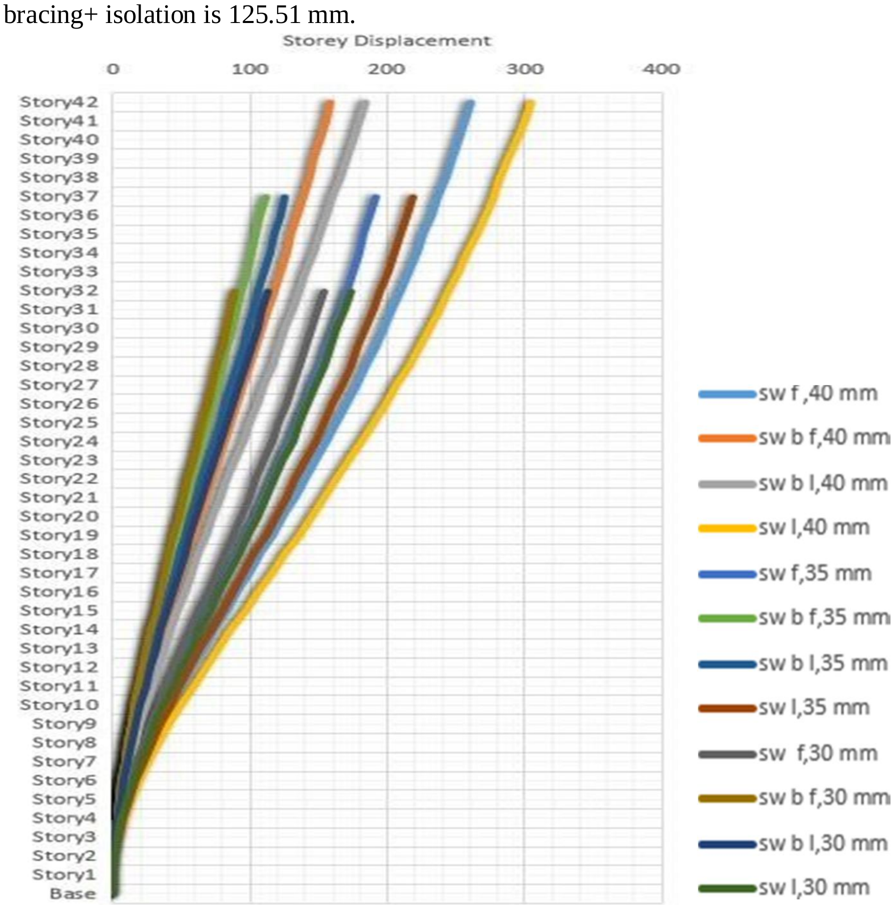

Fig. 4.2 storey displacement vs storey height

Max storey displacement for G+40 storey building in case of model having shear wall+fixed base is 260.92 mm and in case of modal with shear wall+ bracing +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 make structure more ductile, due to thisductility in the structure tends to displace.

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C. 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 the storey drift divided by the storey height. Storey drift is the lateral displacement of a floor relative to the floor below. The storey drift ratio is an 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 modal with shear wall+ bracing + fixed base is 0.00129 while storeydrift is observed to increase in modal with shear wall + isolation to 0.00228 & in modal withshear 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 modal with shear wall+ bracing +fixed base is 0.00165 while storeydrift is observed to increase in modal with shear wall + isolation to 0.00251 & in modal withshear 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 modal with shear wall+ bracing +fixed base is 0.00153 while storeydrift is observed to increase in modal with shear wall + isolation to 0.00273 & in modal withshear wall+ bracing+ isolation is 0.0016.

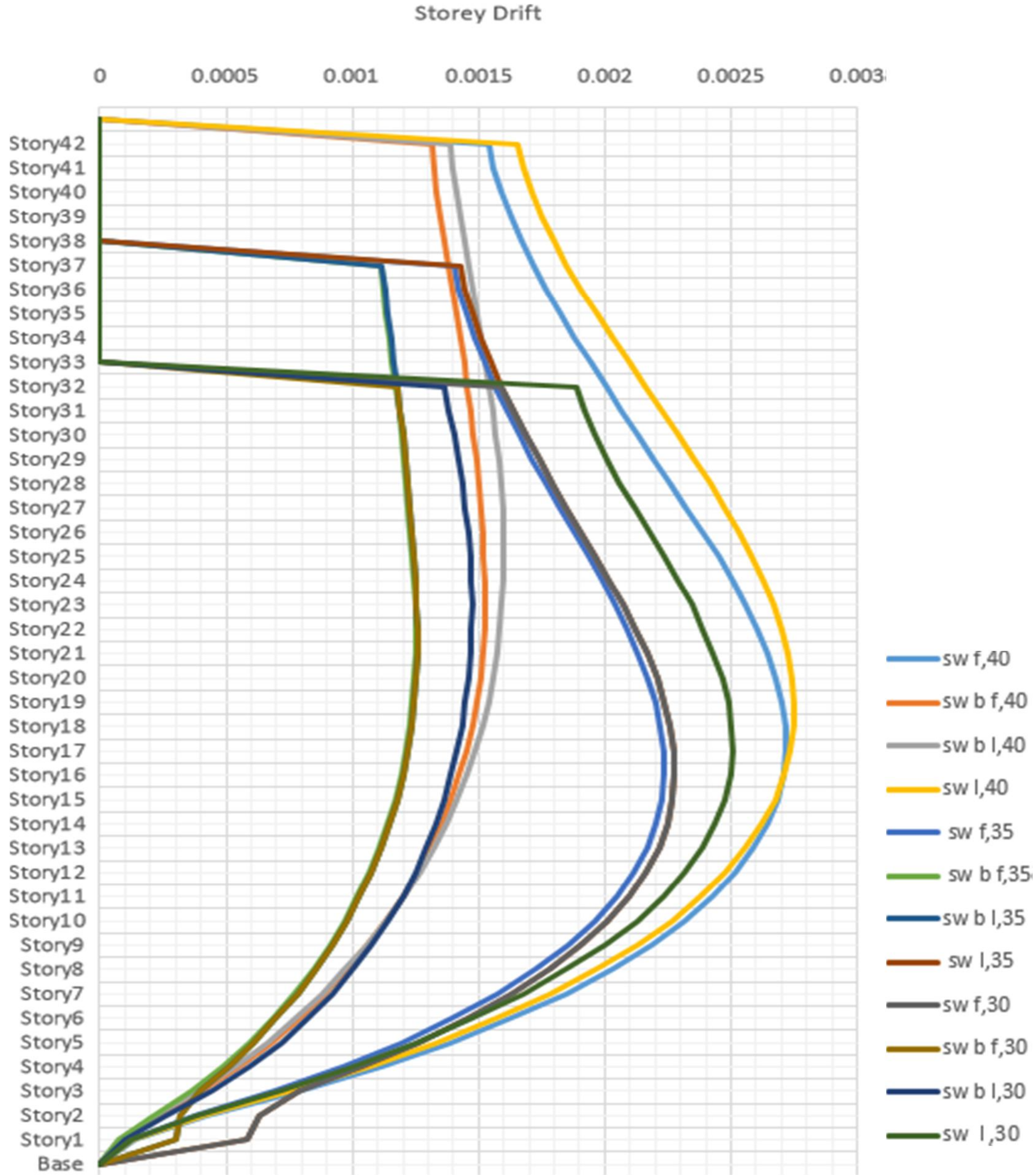

Fig. 4.3 storey drift vs storey height

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D. Base Shear

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 base shear of different models at base in KN

The Base shear of lrb base as compared to fixed base is reduces, this reduction in base shear is 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 3621and 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 & in modal with shearwall+ bracing+ isolation is 1694.38

Base shear for G+35 storey building in case of model having shear wall+ fixed base is 4099and 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 2516.786 & in modal with shearwall+ 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 baseshear is observed to decrease in modal with shear wall + isolation to 2875.33 & in modal with shear wall+ bracing+ isolation is 2837.41

E. 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 . Response spectrum analysis of all the structure for all the model are performed. The storey overturningmoment 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 & in modal with shear wall+ bracing+ isolation is 124273.9KN-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 shearwall + 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 shearwall + 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

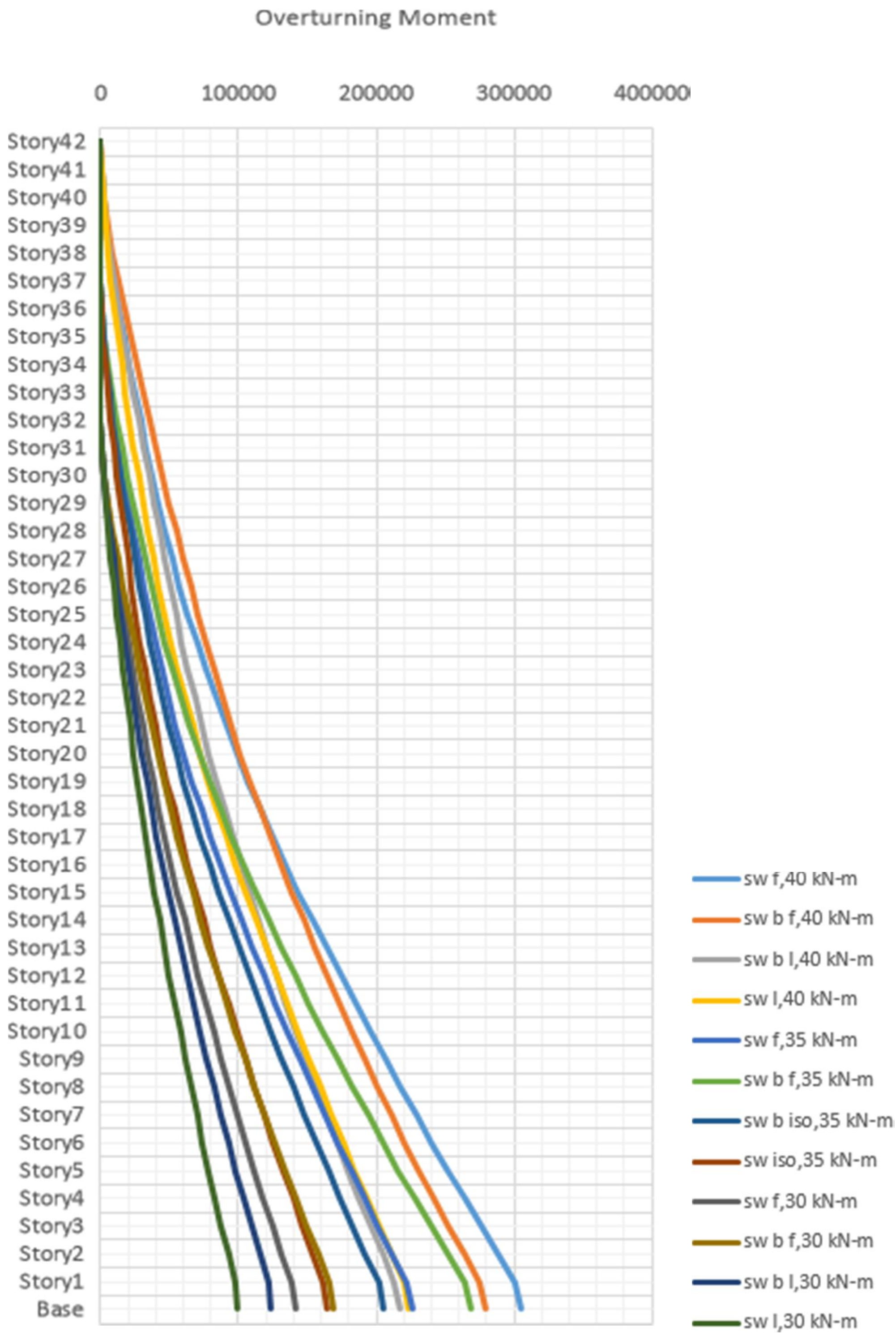

Fig. 4.5 Overturning moment vs storey height

V. CONCLUSION & FUTURE SCOPE

A. Conclusion

1) The results of analyzed LRB base and fixed base for G+30, G+35&G+40 storey are presented 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 thefloors are within the allowable limits according to the code's limits. LRB base gives moreductility 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 reduces which helps to reduce the costof the foundation, due to less overturning moment. Base isolated structures are the best solution for tall structures in earthquake prone zone.
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.

B. 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 suggest that building has gain some flexibility which will results inabsorbing 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 building is 29.80% to 41.68% in 30,35 and 40 storey building with respective lateral supportingelements. which will result in reducing steel reinforcement of the building
4) Time period of building can be adequately increased by using LRB as compared to fixedbase 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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