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Effectiveness of Base Isolation in RC Building using LRB (Lead Rubber Bearing)

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Abstract
This study compares the seismic responses of a fixed base building with a base isolated building as well as as doing a parametric study of a base isolated building.Three regular (G+5, G+8 and G+11) RC fixed base building models were prepared and assigned with Lead Rubber Bearing (LRB) for the base isolation and the flexible base isolated models were prepared.The fixed and isolated building models were analyzed and compared using the Response Spectrum Method as per NBC: 105:2020 and UBC-1997.The comparison among all the models illustrated that after base isolation the fundamental time period of the building increases approximately by two times. The base shear reduces approximately by about 40.8%, 38.7% and 37.6% in six, nine and twelve storey building models respectively. The storey drift decreases approximately by 19.6%, 31.2%and 35% in six, nine and twelve storey building respectively and the maximum lateral displacement of the top floor increases approximately by 57.8%,47.8%and 21.7% in six nine and twelve storey buildings respectively.

Keywords
Base Isolation, Lead Rubber Bearing, Response Spectrum Analysis

1. Introduction

Base isolation is one of the most popular and efficient ways to protect buildings from the effect of earthquakes which also effectively controls the structure's seismic response [1]. The basic idea behind base isolation is to alter the building's response to allow the earth to move beneath it without transferring those motions into the structure itself.Decoupling the seismic energy from ground motion lowers the ductility demand and inter-story drifts by keeping the seismic energy from entering the building. In order to achieve this uncoupling,low horizontal stiffness structural elements are positioned between the foundation and the superstructure.This lowers the fundamental frequency of structural vibration and offers a way to dissipate energy,which lessens the acceleration that is transmitted to the superstructure [2]. The Base Isolation shields the structure and its non-structural elements from seismic activity in this way [3]. Base isolators with significant horizontal motion flexibility are introduced in base isolation systems. The fundamental frequency of the system drops to a lower value with the placement of base isolators between the superstructure and substructure [4]. The structure is less likely to collapse if the inherent frequencies of the building can be modified to ones that do not coincide with the frequencies of earthquakes. The base isolation operates in a similar way; by lowering the structure's frequencies, it lessens stiffness. In other words, the base isolators permit the structure to travel over the ground, reducing their frequency [5].

1.1 Lead Rubber Bearing (LRB)

Lead rubber bearing is one of the earliest bearings utilized in base isolation of structures.[6] With its alternating layers of steel and rubber surrounding the lead core, the lead rubber bearing dissipates energy, offers high axial stiffness and low lateral stiffness and uses heavy damping.For lead-plug bearings, the maximum shear strain range varies depending on the manufacturer, but it typically falls between 125% and 20% [7]. Steel shims are used to reinforce the cylindrical rubber bearings found in LRB isolators. Rubber and shifts are arranged in alternating layers and the isolator has steel plates on both ends. Therefore, it is vital to examine the impact of base isolation in different building types using various isolators due to the benefits and ability of base isolation using LRB in reducing the effects of earthquakes.

2. Methodology

In this study at first modelling of finite element model without consideration of base isolation is done in ETABS. Design of Lead Rubber Bearing (LRB) is done as per UBC-1997[8] and is assigned in the building models and response spectrum analysis is carried out as per NBC: 105:2020 in each fixed base model and both NBC: 105:2020 and UBC1997 in base isolated structure.

2.1 Building Models

In ETABS 19, RC- framed structures with and without an LRB was modelled.LRB was positioned at the base of each column of the construction and the structure is regarded as a moment-

Table 1: Beam and columns sizes

S. N	No of Storey	Beam size(mm)	Column size
1	Six	400× 450	450× 450
2	Nine	500× 500	450× 600
3	Twelve	600× 600	500× 600

resisting frame. For this purpose, the seismic zone V and soil type D is considered. Table 1 and Table 2 lists the key attributes of the buildings.

Table 2: Sailent features of modeled structures

S. N	Item	6,9 and 12 storey
1	Grade of concrete	M25
2	Grade of concrete	Fe415
3	Density of concrete	25 KN/m^3
4	Storey height	3m
5	No of bays	4 on each side
6	Slab thickness	125m
7	Live load	2 KN/m^2
8	Wall load exterior	11.24KN/m^2
9	Wall load interior	8.44KN/m^2

2.2 Design of LRB

The design of Lead Rubber Bearing (LRB) is done as per NBC: 105:2020 and UBC-1997. In the context of Kathmandu Valley, the soil type falls under Type D, characterized by very soft soil with an undrained shear strength below 12.5 Kpa. While an exact match for this soil type in the Uniform Building Code (UBC-1997) might not exist,the soil type S_E in the UBC-1997 exhibits similar characteristics. Therefore, utilizing the parameters and guidelines set for soil type S_E in UBC-1997 allows for the computation of seismic coefficients such as Cv and Ca. This approach enables the design of Lead Rubber Bearings in accordance with the seismic provisions of UBC-1997, even in the absence of an exact soil type match.

Design Parameters

- Seismic Zone = V
- Seismic Zone Factor (Z) = 0.35
- Soil Profile Type = Very soft
- Seismic Coefficient Ca = 0.36
- Seismic Coefficient Cv (CVD) = 0.9
- Maximum compression load on column for 6 storey building = 1235.89KN
- Maximum compression load on column for 9 storey building = 1801.6KN
- Maximum compression load on column for 12 storey building = 3197.76KN
- Design time period, T_D = 2 sec
- Shear modulus, G = 0.7 Mpa
- Bulk modulus, K = 2000
- Effective damping,$ß_D$ = 0.05
- Damping coefficient,B_D = 1
- Maximum shear strain of rubber, γ = 100%

After calculating the required parameters we input these values in ETABS and assign LRB in the base of each columns.

Table 3: Input values in ETABS for 6 storey

Input values	Six Storey
Rotational inertia	0.021423 KN/m
Effective stiffness(U1)	796590.03 KN/m
Effective stiffness(U2, U3)	796.59 KN/m
Effective damping(U2, U3)	0.05
Yeild displacement(U2, U3)	0.0050769 m
Stiffness	7340.25 KN/m
yeild strength	40.56 KN

Table 4: Input values in ETABS for 9 storey

Input values	Nine Storey
Rotational inertia	0.047344KN/m
Effective stiffness(U1)	1161213.3KN/m
Effective stiffness(U2,U3)	1161.21KN-m
Effective damping(U2,U3)	0.05
yeild displacement(U2,U3)	0.0052876m
Stiffness	10699.62KN/m
yeild strength	56.58KN

Table 5: Input values in ETABS for 12 storey

Input values	Twelve storey
Rotational inertia	0.15708KN/m
Effective stiffness(U1)	2061102 KN/m
Effective stiffness(U2,U3)	2061.102 KN-m
Effective damping(U2,U3)	0.05
yeild displacement(U2,U3)	0.0058245m
Stiffness	1899.22 KN/m
yeild strength	100.36

3. Result and Discussion

Three distinct building models were constructed, differing in height with six, nine, and twelve stories respectively. These structures were equipped with Lead Rubber Bearing (LRB). To assess their response to dynamic loading, particularly considering seismic activity, analysis was conducted using the Response Spectrum method as per NBC 105:2020.The investigation aimed to compare the outcomes between fixed base buildings and isolated base buildings.The software tool Etabs19 was utilized for modeling and simulation, considering variations with and without LRBs. The focus of the analysis was to evaluate and contrast the seismic responses of fixed base models against those employing isolated bases, thus highlighting the impact of LRBs on structural behavior under dynamic loading conditions.

3.1 Base Shear

The comparative analysis of base shear between fixed base and isolated base building models revealed substantial reductions in seismic forces when Lead Rubber Bearings (LRBs) were incorporated. For instance, in the case of the six-story buildings, those equipped with LRBs exhibited a remarkable 40.84**%**and 40.47**%** reduction in base shear in the X and Y directions respectively, compared to their fixed base counterparts. Similarly, the nine-story isolated base structures showcased reductions of 38.74**%** and 38.69**%** in base shear along the X and Y axes respectively, when compared to their fixed base equivalents. Moreover, the twelve-story buildings with LRBs demonstrated significant decreases of 37.62**%** in both X and Y direction base shear in contrast to the twelve-story buildings without LRBs. These findings underscore the pronounced effectiveness of LRBs in mitigating seismic forces across varying building heights, highlighting their role in enhancing structural resilience against dynamic loads.

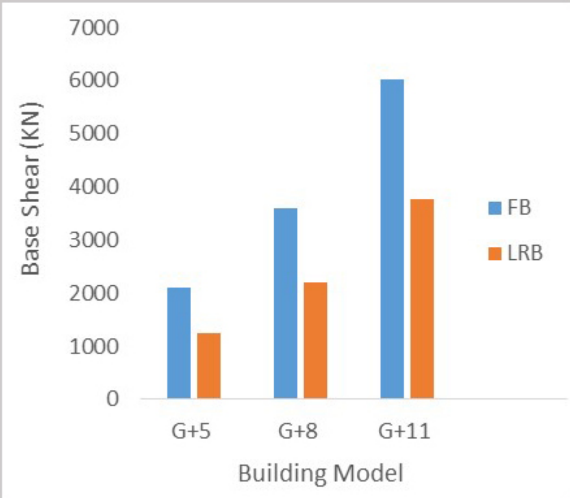

Figure 1: Base Shear in X direction

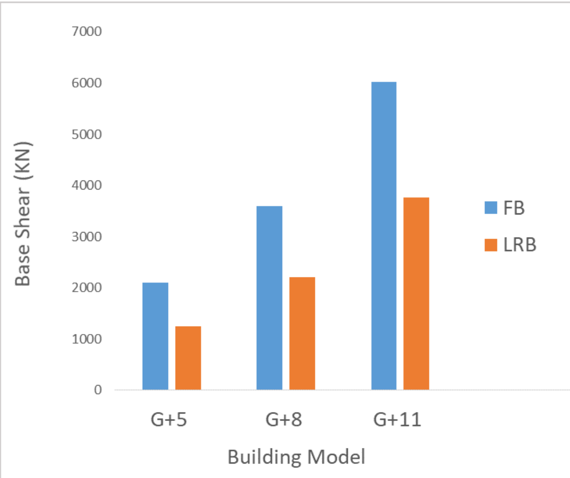

Figure 2: Base Shear in Y direction

3.2 Time Period

The time period of a building, which indicates how quickly it oscillates in response to seismic forces, is closely linked to its stiffness.When comparing base isolated structures to fixed base buildings,the time period of base isolated structures tends to be roughly twice as long as that of their fixed base structures.This elongation in the time period signifies a crucial aspect of base isolation, showcasing how these structures exhibit a more deliberate and extended response to seismic activity due to their design and the incorporation of isolation mechanisms. This significant increase in time period underlines the altered dynamics and enhanced resilience of base isolated structures, showcasing their ability to withstand and effectively dissipate seismic energy.

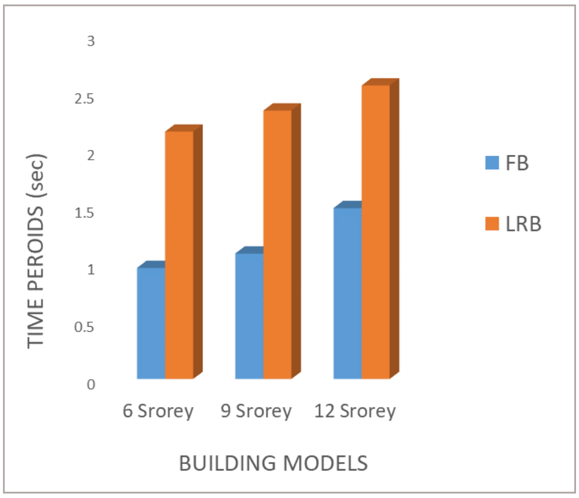

Figure 3: Time Period in X direction

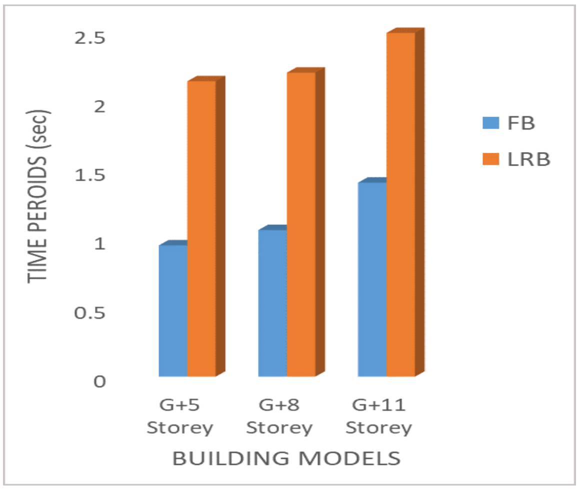

Figure 4: Time Period in Y direction

3.3 Storey stiffness

The overall flexibility of these buildings is significantly increased by the installation of Lead Rubber Bearings (LRBs) at the base. In contrast, the storey stiffness that is, the resistance provided by each floor level of regular structures with fixed bases is generally higher throughout the building. On the other hand, compared to structures with fixed bases, there is a noticeable decrease in storey stiffness in structures that use isolated bases with LRBs. It's interesting to note that the building's lower storeys exhibit a greater reduction in storey stiffness than its upper ones. This trend suggests that the different storeys of the building are affected differently by LRBs in terms of flexibility, with a greater decrease in stiffness at the lower levels.

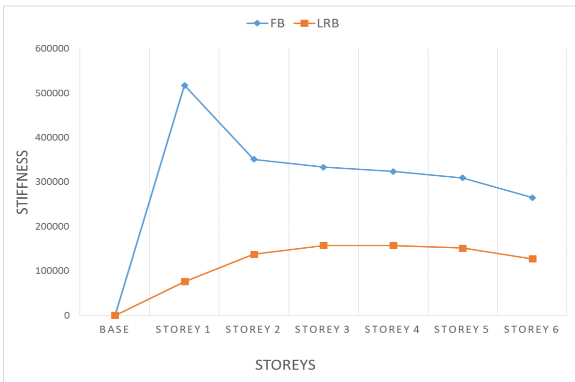

Figure 5: Stiffness of 6 storey building in X direction

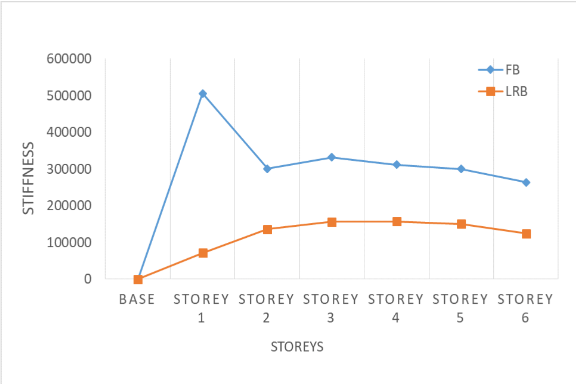

Figure 6: Stiffness of 6 storey building in Y direction

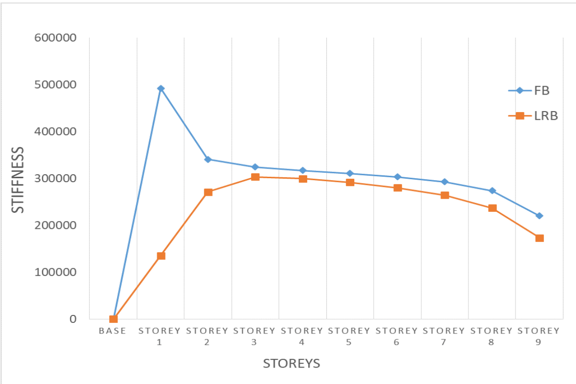

Figure 7: Stiffness of 9 storey building in X direction

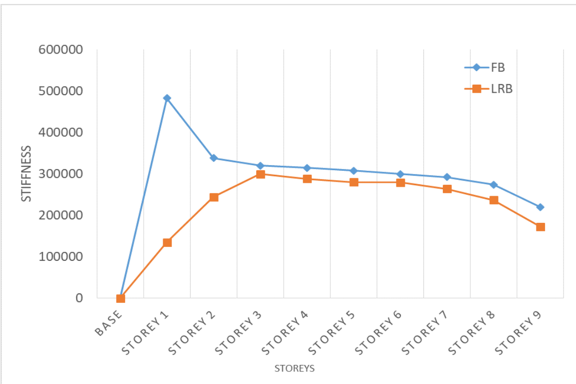

Figure 8: Stiffness of 9 storey building in Y direction

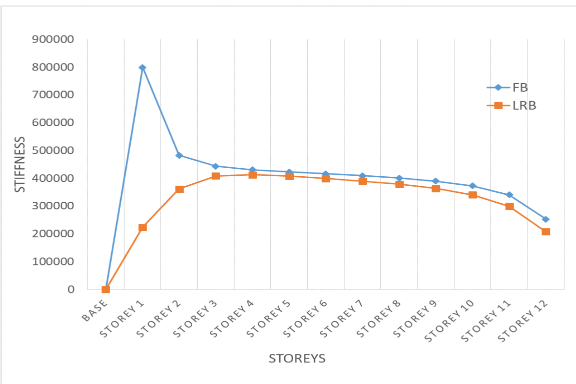

Figure 9: Stiffness of 12 storey building in X direction

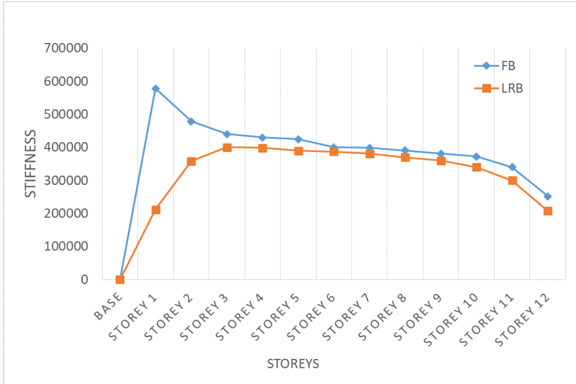

Figure 10: Stiffness of 12 storey building in Y direction

3.4 Storey Drift

There is a noticeable reduction in storey drift after the structures are fitted with Lead Rubber Bearings (LRBs). More specifically, at various building heights, there is a noticeable decrease in the maximum storey drift. For the six, nine, and twelve-story buildings, the reduction is 19.63**%**, 31.2**%**, and 35**%** in the X direction, respectively. Similarly, the maximum storey drift for each building height decreases by 17.36**%**, 32.39**%**, and 42.32**%** in the Y direction. These results demonstrate the significant efficiency of LRBs in reducing lateral movement within the structures; larger buildings show significantly greater decreases in storey drift after LRB installation.

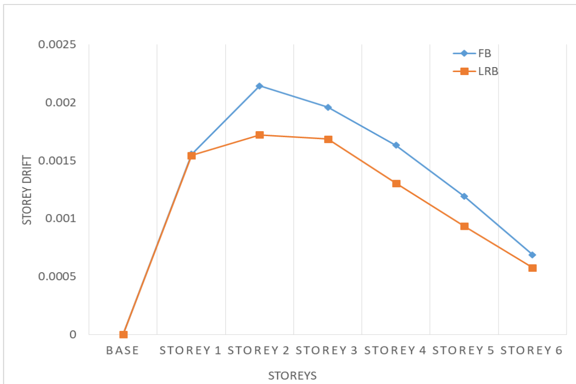

Figure 11: Storey Drift of 6 storey building in X direction

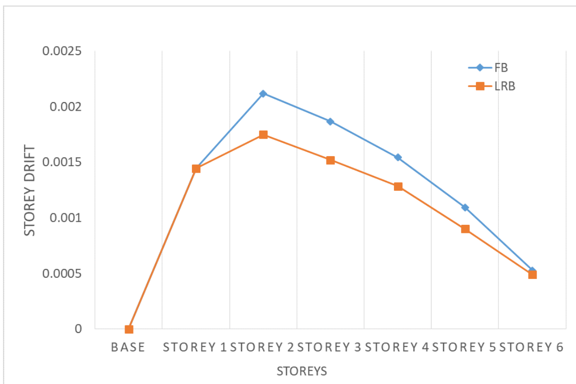

Figure 12: Storey Drift of 6 storey building in Y direction

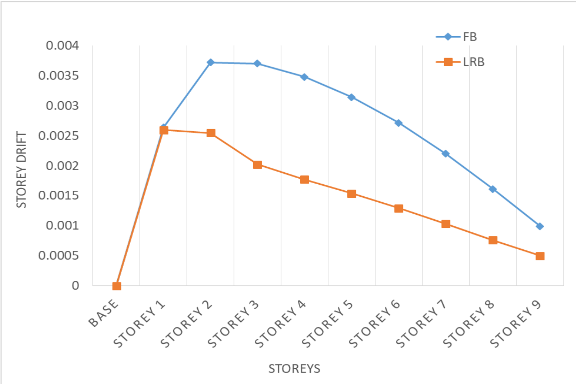

Figure 13: Storey Drift of 9 storey building in X direction

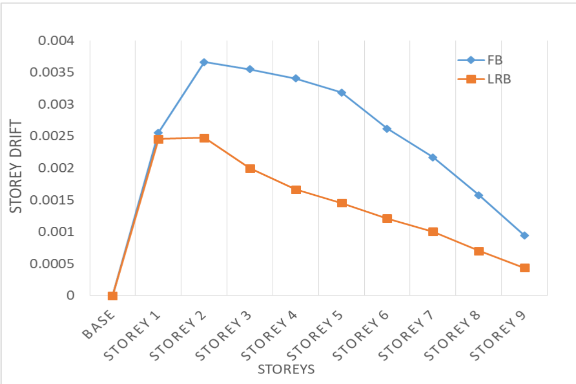

Figure 14: Storey Drift of 9 storey building in Y direction

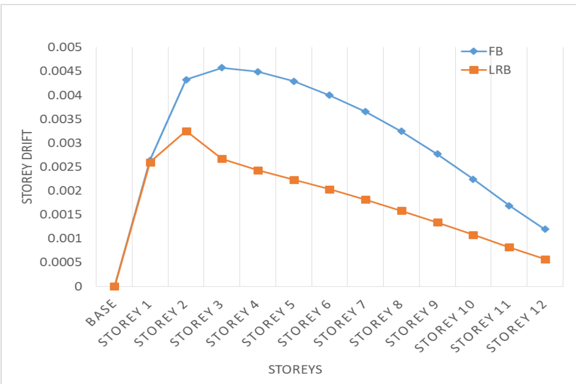

Figure 15: Storey Drift of 12 storey building in X direction

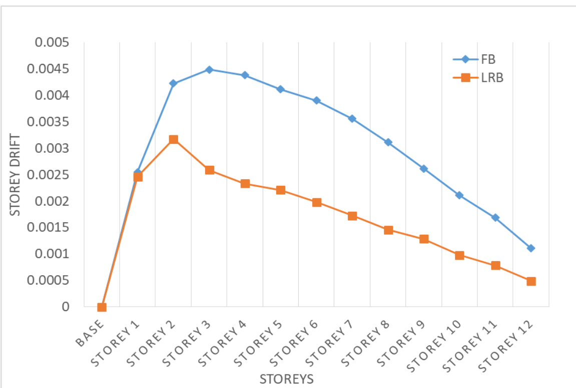

Figure 16: Storey Drift of 12 storey building in Y direction

3.5 Maximum Storey Displacement

The maximum lateral displacement of the structures increases noticeably after base isolation. More specifically in buildings of varying heights, this increase is noticeable on the upper floor. For the six, nine, and twelve-story buildings, respectively, the maximum lateral displacement of the top floor increases by 57.8**%**, 47.8**%**, and 21.7**%** in the X direction. Similarly, for each building height, the maximum lateral displacement of the top floor increases by 57.27**%**, 47.81**%**, and 21.60**%** in the Y direction. According to these results, base isolation reduces some lateral movement within the structure, but at the highest floor levels it causes a greater lateral displacement, with the amount of increase differing depending on the height of the building.

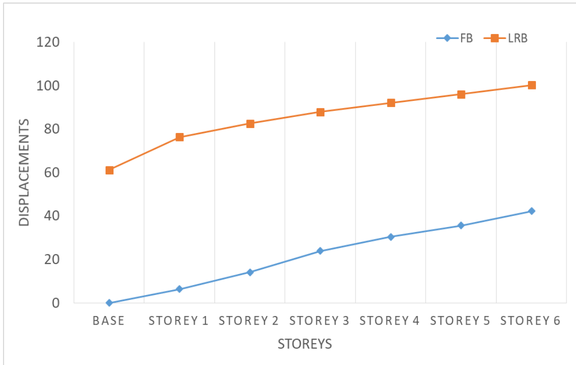

Figure 17: Lateral Displacement of 6 storey building in X direction

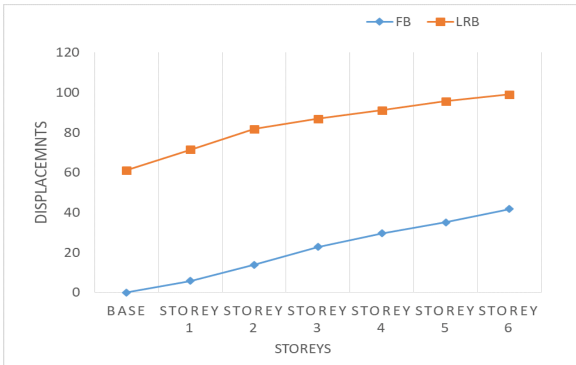

Figure 18: Lateral Displacement of 6 storey building in Y direction

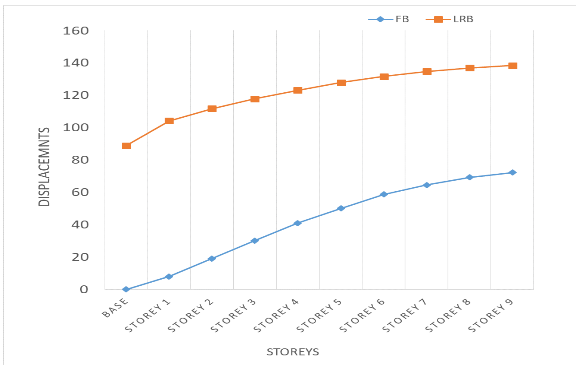

Figure 19: Lateral Displacement of 9 storey building in X direction

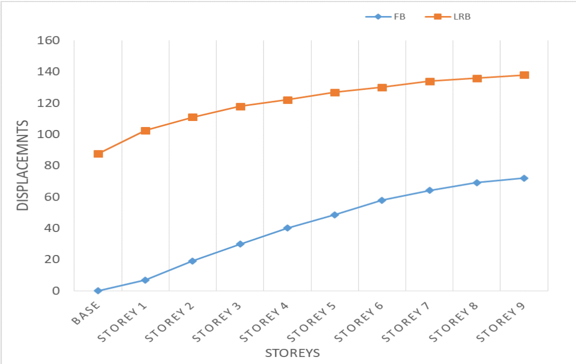

Figure 20: Lateral Displacement of 9 storey building in Y direction

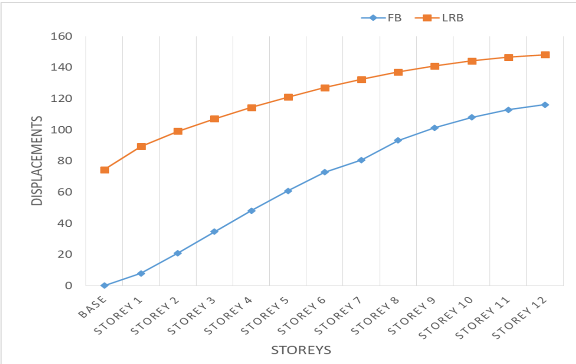

Figure 21: Lateral Displacement of 12 storey building in X direction

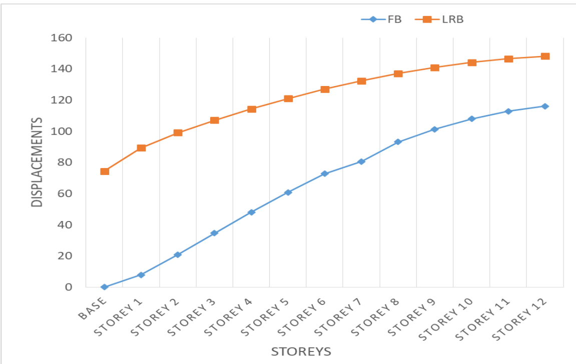

Figure 22: Lateral Displacement of 12 storey building in Y direction

4. Conclusion

A typical reinforced concrete public building has been considered for the study. The building is modelled in Etabs 19. Six different model was modeled for 6, 9 and 12 storey structure with . Dynamic analysis of the building (Response Spectrum) with and without LRB is carried out.Results are compared in terms of percentage reduction in base shear storey drift and storey stiffness as well as percentage increase in natural time period and maximum lateral displacement of building. On the basis of the results obtained from the analysis, the following conclusions are made:

The base shear in the six storey,nine storey and twelve storey buildings assigned with LRB reduces by 40.84**%**, 38.74**%**, 37.62**%** respectively in X direction and 40.47**%**, 38.69**%**, 37.62**%** in Y direction as compared to the fixed base six ,nine and twelve storey buildings.The storey drift in the structures decreases after the assignment of LRB and the reduction of maximum storey drift is by 19.63%, 31.2% and 35% in X direction and 17.36%, 32.39% and 42.32% in Y direction in six ,nine and twelve storey building respectively. The increase in the time period of the base isolated structure is seen to be approximately two times in comparison with the fixed base buildings in both X and Y directions.The storey stiffness in the structures decreases after the assignment of LRB and the maximum lateral displacement of the structures increases after base isolation . The maximum lateral displacement of the top floor increases by 57.8% ,47.8% and 21.7% in X direction and 57.27% , 47.81% and 21.60% in Y direction in six ,nine and twelve storey building respectively.

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