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Comparative Analysis of G+15 Building with and Without Lead-Bearing Rubber Base Isolators Using Etabs

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***Abstract:** The main principle of this project is to protect the buildings by constructing them as earthquake-resistant structures. Base Isolation is a flexible layer between the substructure and superstructure uncoupling the structure from damaging effects from ground motion to resist the vibrations in the structure. It is important to use high technology like base Isolation which protects the structure against extreme earthquakes without sacrificing the performance of the structure. The comparative study is conducted on a G+15 story building with and without Lead Rubber bearing in which IS 875:52015, IS 1893:2016 using the response spectrum method. Considering the maximum vertical reaction obtained from the fixed base is used to design base isolators the obtained stiffness is used in modeling by replacing the fixed base joins to base isolators in the buildings. Story displacement, Story drift, story, and Overturning moment shear are compared for both cases. In this case, we are using rubber base isolators for analyzing the structure using ETABS Software.*

***Keywords**: Base Isolation, Lead Rubber Bearing (LRB), Response Spectrum Method, Base Shear, Story displacements, Story drifts, Overturning moment*

I. INTRODUCTION

One of the most commonly used and recognized systems for seismic protection is base isolation. This technique mitigates earthquake effects by essentially separating the structure and its contents from the potentially damaging ground motion, particularly within the frequency range that most affects the building. In India many buildings are currently constructed on fixed bases, meaning they are built directly on the ground. During an earthquake, as the ground shakes, these buildings sway in response. A severe earthquake can cause critical parts of the building's infrastructure, such as walls and columns, to collapse, potentially leading to the entire building falling. A base isolation system, however, involves placing bearings, known as "base isolators" between the building's floor and its foundation.

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These base isolators absorb the shock of an earthquake and significantly reduce the shaking's impact on the building.

A. Base Isolation System

The base isolation system in general consists of a bearing allowing horizontal movement which provides the members proper rigidity under the horizontal loads and controls the displacement. The members that are provided have the behavior of being rigid enough to pass the load vertically as well as horizontally. This helps in changing the period of the base isolation system along with the structure above the ground level. It helps in decreasing the inertia forces.

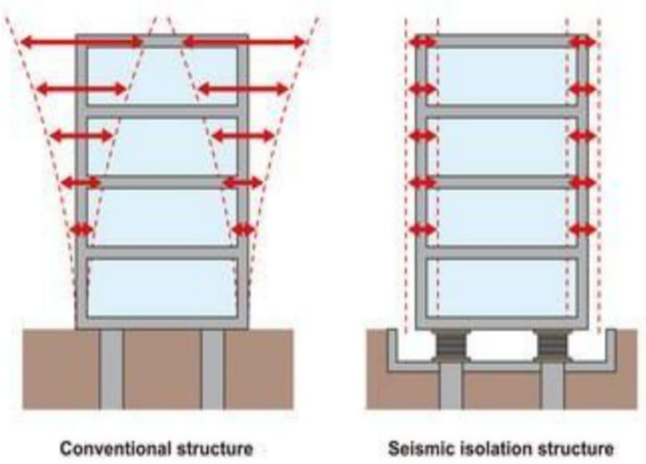

Fig 1: Rubber Base Isolator

When the seismic isolation system is compared with fixed base the displacement of the base isolation system causes big displacements in the superstructure. There are different types of base isolators are used in the base isolation system. Which are made of different materials and their behavior varies depending on the material used.

B. Lead Rubber Bearing

The lead rubber bearing (LRB), invented in Nea Zealand in 1975, comprises a lead plug, endplates, steel shims, and rubber layers. The steel shims are crucial for providing vertical stiffness, while the rubber layers allow for lateral flexibility or horizontal stiffness. The lead core enhances the isolator's stiffness and imparts damping to the system.

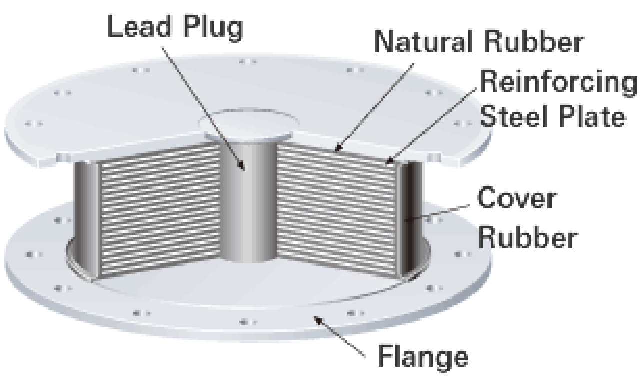

Fig 2: Lead Plug Rubber Bearing

This base isolation technology uniquely combines vertical load support, horizontal flexibility, restoring force, and damping within a single unit. "**The primary principle of base isolation is to adjust the structure's response so that ground movements occur beneath the structure without transmitting these movements to the superstructure**". Ideally, this separation would be complete, but in practical applications, some contact between the superstructure and substructure is necessary, making the LRB an effective base isolator.

II. LITERATURE REVIEW

(Priata R. Saha, 2022, [6][7]) In this research, a 10-story base building located in seismic zone 2 (Dhaka) was modeled, analyzed, and designed using ETABS (version 17.0.1). Additionally, the building was re-evaluated using Lead-rubber bearing (LRB) isolators. Three different types of isolators were specifically designed for the building's central, external, and internal positions, taking into account the normal forces acting at the base. The study presents a comparison of the building's moment, shear forces, and period before and after the installation of the LRB isolators.

(Poonam Mhatre, 2021, [14]) In this research paper, a three-dimensional nonlinear analysis is conducted on a reinforced concrete (RC) residential building. The design and analysis are executed using the SAP 2000 16.0.00 software. The study examines the building's performance with and without the implementation of a base isolator. The primary goal is to assess and compare the efficiency of a building with a fixed base versus one with an isolated base. Laminated rubber bearings are employed as the isolation system.

(Aamir A, 2021[13]) In this research paper, base isolation is explored as an earthquake-resistant design technique, specifically utilizing Lead Rubber Bearing (LRB) isolators as a passive structural vibration control method. The study investigates the seismic behavior of various irregular building models, including a simple model, a re-entrant corner plan irregular model, a mass irregular model, and a stiffness irregular **model**. These configurations are analyzed with different frame sections, both with and without LRB base isolation. The comparative analysis focuses on base shear, story shear, story displacement, story drift, and story acceleration, using data from three different earthquakes.

(Vatsal Srivastava, 2021, [12]) This review paper explores the behavior of structures with and without base isolation systems. Key parameters such as story shear, story displacements, and story drifts are analyzed. The findings indicate a significant reduction in story shear for buildings equipped with base isolation. However, story displacements and story drifts are observed to increase due to the enhanced flexibility of buildings with isolated bases.

(Ravi Kant, [2021, [11]) This study involved analyzing an 8-story building using ETABS software. The introduction of Lead Rubber Isolators significantly reduced story drift, story accelerations, base shear, and lateral shear forces, as well as velocity. Conversely, story displacement increased in both the X and Y directions. These effects were compared across various thicknesses of lead rubber base isolation systems under both near-field and far-field earthquake conditions.

(Shah Richa, 2020, [10]) This research paper analyzes G+2 reinforced concrete (RC) frame buildings under the impact of four different earthquakes: Chamoli, Loma Prieta, and Imperial Valley. The study compares the performance of a conventional RC frame with a fixed base to one equipped with base isolation using lead rubber bearings (LRB). The goal is to assess the effectiveness of base isolation in each earthquake scenario.

(Akshay C.Umare, 2020, [9]) In this research paper, a lead rubber isolator is employed as the isolator for a project involving a G+10 story building. Initially, a model with a fixed base is prepared using the UBS97 and IS 1893 codes, utilizing the response spectrum method. The calculated stiffness is then used to modify the model by replacing the fixed base joints with base isolators. Various parameters such as base reaction, period, story forces, and displacements are recorded and compared.

(AMER HASSAN, 2018, [8][14][15][16][17][18][19]) In this study, lead rubber bearings (LRB) have been designed by standard codes. The crucial aspect of LRB design involves estimating the target period and displacement limits. This paper focuses on the design of LRBs intended for seismic resistance.

(Swapnil Ambasta, 2018, [5]) This paper explores the effectiveness of lead rubber bearings (LRB) for base isolation in comparison to traditional construction methods. The project involves the design, modeling, and analysis of G+6 rigid jointed, plane symmetrical reinforced concrete (RCC) frames under two different scenarios. The first Scenario considers a fixed base, while the second scenario incorporates base isolation using LRB. The study compares building displacements and acceleration between these two cases.

A. Aim and Objective of Work

- The objective of this study is to modify the response of the building by using Lead Rubber Bearing for base isolation of the Structure.
- To compare parameters like story displacements, story drifts, base shear, and Overturning moment to prevent or minimize damage to the structure and its contents cost-effectively.
- To design a rubber base isolator for the RCC building
- To study the effect behavior of isolator for G+15 building structure under the Response Spectrum Method.

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- To study the structure response with LRB base and with Fixed base.

B. Need of Present Work

Improvement for Safety of Building. Reducing damaging deformations in structural and non-structural components. Reducing acceleration response to minimize the damage to protect of Life and safety of occupants. To ensure Structural Reliability without structural damage due to ground shaking of moderate intensities. The need for base isolators is to increase the durability and serviceability of structures.

C. Scope of the Work

- To carry out analysis of G+15 story RC frame with LRB isolator and with fixed base by Response spectrum method as per the provision of IS 1893:2016 and IS 875:2015 using computational software ETABS 17.0.1.
- The seismic behavior of G+15 buildings in region V and site type 3 with and without base isolators were studied.
- The G+15 Building was compared by taking parameters like story shears, floor displacements, and story drifts into consideration.

III. METHODOLOGY

A. Description of Building

Software used for analysis: ETABS
Code provisions: IS 456: 2000
Type of analysis: Response spectrum analysis
Building details:
Structure Type: Regular structure and irregular
Height of Building: 45.2 m
Total No. of Story: G+15
Height of Each Story: 3m
Height of Bottom Story: 3.2m
Beam Size: 400mm x 400mm
Column Size: 450x300mm
Slab Thickness: 150mm.
Material properties
Grade of Concrete: M35 (for Beams, Column and Slabs)
Grade of Steel: HYSD 500
Load consideration
Dead Load:
Beam: 6.75 kN/m
Column: 11.25 kN/m
Slab: 3.75 kN/m2
Live Load: 3 kN/m2
Floor Finish: 2 kN/m2
Seismic load factors and their considerations
Codal provision: IS 1893:2016 [1]
Seismic Zone - V
Zone Factor - 0.36
Soil Category - III
Importance Factor - 1
Response Reduction Factor R - 5
Damping (βeff) – 5%
Wind Load factor and its considerations
Codal provision: IS 875: 2015 (part-3) [2] [3] [4]
Risk co-efficient(k1): 1
Terrain category(k2): 4
Topography (k3): 1
Important factor: 1
Wind speed (vb): 50m/s
Windward co-efficient: 0.8
Leeward co-efficient: 0.5
Where: vb is the basic wind speed m/s
k1 is the probability factor (risk co-efficient)
k2 is the terrain roughness and height factor
k3 is topography factor
k4 is an important factor
vb, k1, k2, k3, k4 values based on the IS 875: 2015 (part-3)

B. Method of Analysis: Response Spectrum Method

Response spectrum method may be performed for any building using the design accelerations or by a site-specific design acceleration spectrum. The response spectrum proves to be valuable in earthquake engineering as it aids in the analysis of a building's and equipment's performance during seismic events.

Table 3.1: Response Spectrum Analysis

Property Name	Response Spectrum Analysis
Effective Stiffness Keff(R)	4090.732 KN/m
Horizontal Stiffness KH	4073.732KN/m
Vertical Stiffness KV	1662965.155KN/m
Yield strength QR	122.1779 KN
Post Yield Stiffness ratio	0.1
Damping	5%

C. Modelling of Building

Using ETAB software, G+15 building models are created.

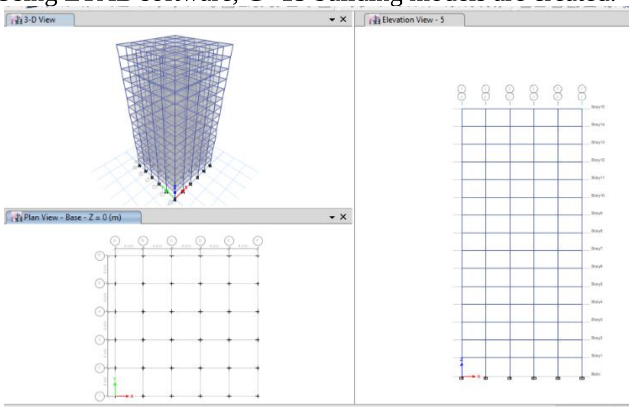

Figure 3: Shows the G+15 Building without Base Isolation 3-D view, Elevation, and Plan

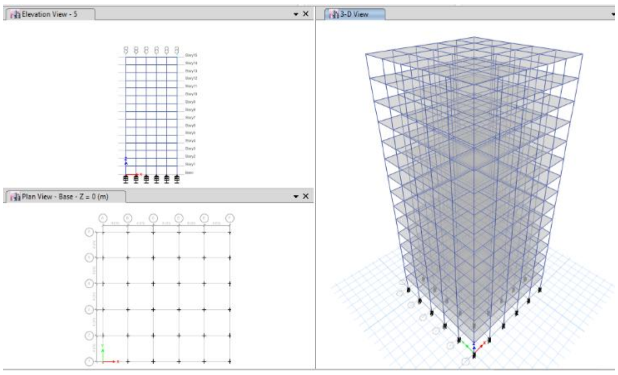

Figure 4: Shows the G+15 Building with Base Isolation 3-D view, Elevation, and Plan

IV. RESULTS AND DISCUSSIONS

Results estimated from the study of conventional high-rise structures and minivan high-rise structures with different shapes by using computer software ETABS under earthquake loading. The Details of Different prepared software models which include total height, wall type thickness, and shape of a building considered for the analysis

A. Maximum Displacement(mm)

Table 4.1: Maximum Displacement

No. of Story's	Story Shear		% Difference
	Fixed Base	Base Isolator	
15	250.203	306.527	18.37
14	245.777	302.198	18.67
13	239.295	295.881	19.12
12	230.722	287.534	19.76
11	220.134	277.224	20.59
10	207.613	265.023	21.66
9	193.239	251.005	23.01
8	177.091	235.24	24.71
7	159.245	217.798	26.88
6	139.776	198.746	29.67
5	118.756	178.152	33.34
4	96.257	156.077	38.32
3	72.353	132.54	45.41
2	47.172	107.242	56.01
1	21.308	76.424	72.04
Base	0	0	0

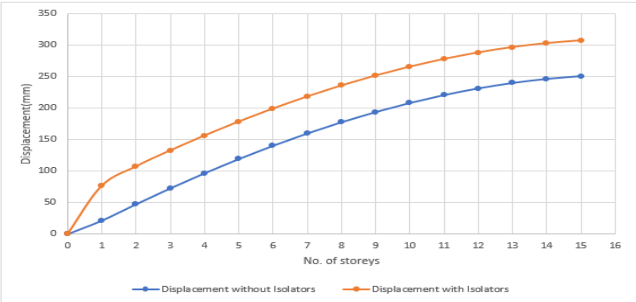

Fig 5: Structure Maximum Displacement without and with Base Isolator

Maximum story displacement means the displacement that occurred at each story level because of various loading patterns. From Fig 5 it is observed that in base-isolated structure story displacement at story 1 increased by 72% when compared to fixed base structure.

B. Story Drift (Unitless)

Table 4.2: Maximum Story Drift

No. of Story's	Max story drift		% Difference
	Fixed base	Base isolators	
15	0.001475	0.00144	2.67
14	0.00216	0.0021	2.65
13	0.002858	0.00278	2.62
12	0.003529	0.00344	2.61
11	0.004174	0.00407	2.56
10	0.00479	0.00467	2.46
9	0.005383	0.00526	2.38
8	0.005949	0.00581	2.27
7	0.00649	0.00635	2.16
6	0.00700	0.0068	2.03
5	0.0075	0.00736	1.89
4	0.007968	0.00785	1.53
3	0.008393	0.00844	-0.474
2	0.00862	0.01027	-16.09
1	0.00665	0.0238	-72.11
Base	0	0	0

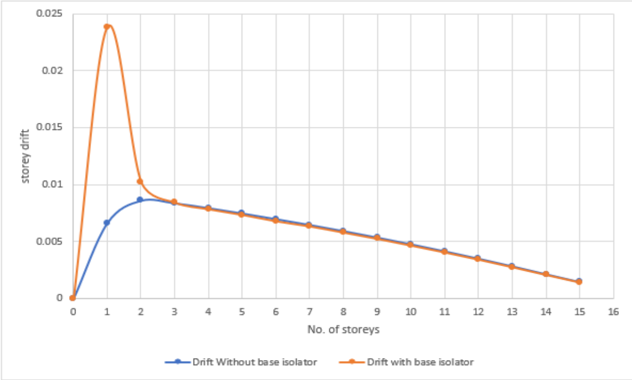

Fig 6: Structure Maximum Story Drift without and with Base Isolator

Story drift is the relative displacement between any two levels of the story between the floor above and below the under consideration. As per the IS1893-2002 story drift is 0.004 times the story height. From Fig 6 it is observed that story drift is reduced by about 2.67% after using the lead rubber bearing provided as base isolation for the RC Building.

C. Story Shear(kN)

Table 4.3: Story Shear

No. of Story's	Story Shear		% Difference
	Fixed Base	Base Isolator	
15	838.347	809.809	3.40
14	1664.459	1608.843	3.34
13	2459.566	2380.593	3.21
12	3225.951	3127.057	3.06
11	3965.902	3850.251	2.91
10	4681.704	4552.187	2.76
9	5375.641	5234.876	2.61
8	6049.999	5900.332	2.47
7	6707.064	6550.5646	2.33
6	7349.122	7187.586	2.19
5	7978.457	7813.408	2.07
4	8597.355	8430.044	1.95
3	9208.102	9039.504	1.83
2	9812.982	9643.800	1.72
1	10414.289	10244.951	1.63
Base	0	0	0

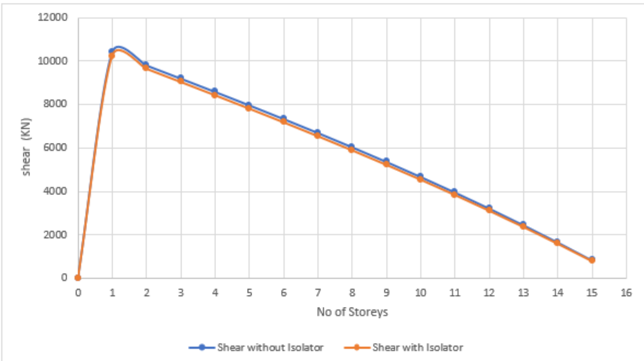

Fig 7: Structure Maximum Story Shear without and with Base Isolator

The design seismic force to be applied at each floor level is called story shear as the height is decreasing the story shear will have maximum value.

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From Fig 7 it is observed that in base-isolated structure story shear at story 15 reduced by 3.4 % when compared to fixed base structure.

D. Overturning Moment

Table 4.4: Overturning Moment

No. of story's	Overturning Moment (KN-m)		% Difference
	Fixed Base	Base Isolator	
15	0	0	0
14	2515.049	2429.427	3.404
13	7508.420	7255.971	3.362
12	14887.119	14397.751	3.287
11	24564.974	23778.924	3.199
10	36462.683	35329.678	3.107
9	50507.795	48986.24	3.013
8	66634.718	64690.870	2.917
7	84784.717	82391.867	2.822
6	104905.911	102043.561	2.728
5	126953.278	123606.319	2.636
4	150888.649	147046.546	2.54
3	176680.715	172336.679	2.458
2	204305.021	199455.594	2.37
1	233743.969	228386.594	2.291
Base	267069.696	261170.438	2.208

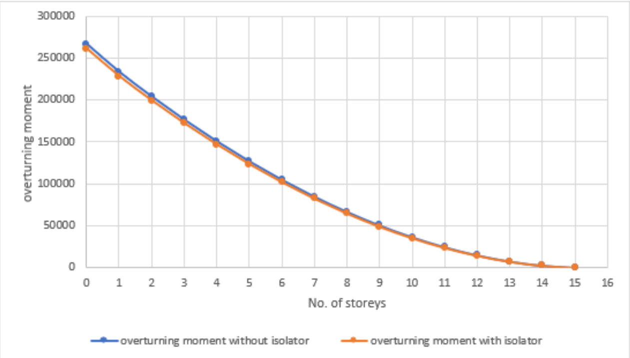

Fig 8: Structure Maximum Overturning Moment without and with Base Isolator

From Fig 8 it is observed that in the base-isolated structure, the Overturning moment at story 14 was reduced by 3.4% when compared to the fixed base structure.

V. CONCLUSION

The following conclusions are made based on the results obtained from the analysis The conclusions drawn from the analysis of G+15 buildings with and without LRB are as follows

- Story shear is reduced after the lead rubber bearing (LRB) is provided as a base isolation system which reduces about 3.404% for the 15-story RC Building.
- Story drift is reduced by about 2.67% after using the lead rubber bearing provided as base isolation for the RC Building in the X-direction.
- Maximum displacements are increased by about 18.37% in story 15 after providing LRB which is important to make a structure flexible during the earthquake for Seismic X-direction.
- Overturning moment reduced by about 3.404 % in story 14 after using the lead base bearing as base isolation for the RC Building.
- Finally, it is concluded that after LRB is provided as a base isolation system it increases the stability of the structure against earthquakes and reduces reinforcement hence making the structure economical.

VI. SCOPE OF FUTURE STUDY

A base isolator, known for its high deformation potential, enables significant drift at the isolation interface, leading to a substantial reduction in seismic response. Analysis can be conducted by altering the story height and increasing the number of stories. Various geometric configurations can also adopt different base isolation systems. This research was limited to a single, regular 15-story building model. Future studies could explore diverse building configurations. Additionally, future research could involve implementing different types of base isolation systems in similar models. Investigations could extend to various structural systems such as diagrids, bundle tubes, shear frames, and bracing systems, both with and without base isolation. Further studies could also examine irregular structures, comparing High Damping Rubber Bearings (HDRB) and Lead Rubber Bearings (LRB)

DECLARATION STATEMENT

After aggregating input from all authors, I must verify the accuracy of the following information as the article's author.

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- **Funding Support:** This article has not been sponsored or funded by any organization or agency. The independence of this research is a crucial factor in affirming its impartiality, as it has been conducted without any external sway.
- **Ethical Approval and Consent to Participate:** The data provided in this article is exempt from the requirement for ethical approval or participant consent.
- **Data Access Statement and Material Availability:** The adequate resources of this article are publicly accessible.
- **Authors Contributions:** The authorship of this article is contributed equally to all participating individuals.

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