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Investigating the Impact of Lead Rubber Bearings on Sesmic Behaviour in Elevation for Both Regular and Irregular Frames Using ETABS Software

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Abstract: Building structures can be effectively protected from seismic activity with base isolations, as is well known. This paper looks into how real ground motions affect RCC moment-resisting frames nonlinear response when lead rubber bearings (LRB) are used. This is accomplished by evaluating 12-storey regular and irregular RCC structures in elevation that have been upgraded with LRB based on local as well as global deformations. The LRB is characterized by key parameters: storey drift, base shear, storey moment, torsion, time period, and frequency. Two-dimensional models of the base-isolated frames are meticulously developed using ETABS software, and a series of response spectrum analysis are executed using diverse earthquake ground motions. The seismic behaviour of both the base-isolated and fixed-base frames are comprehensively assessed, considering isolator drift ratio, normalized base shear, base moment, time period, and frequency. The study shows the enhanced performance of base-isolated frames compared to fixed-base frames.

The results, obtained through analysis conducted with ETABS software, reveal a significant elongation of the building period and a notable reduction in building storey moment, torsion, storey drift ratio, and shear force for the isolated building in contrast to the fixed-base building.

Key words*:* Seismic isolation, base isolation system, the storey drift, the shear force, the bending moment, and building torsion are all modelled by the lead rubber base isolation system in ETABS.

1.Introduction

Designing buildings to resist earthquakes focuses on keeping them safe and comfortable by managing internal forces and movements within certain limits. One common strategy is to use structural elements that absorb and dissipate seismic energy, helping to counteract earthquake forces. However, even with these measures, buildings might still suffer damage in very strong earthquakes. An alternative approach should either develop seismic energy dissipation structures or separate the structure from the ground, devices in strategic places. This method can offer even greater protection by reducing the impact of seismic forces and minimizing the risk of significant structural damage.

Given the significant threat earthquakes pose to both social and economic stability, it's vital that earthquake mitigation solutions perform well during expected seismic events. Seismic isolators and energy dissipating devices are effective tools for this purpose. They can be integrated within either positioned between the structures to absorb earthquake force or foundation and the building's structural system to lessen the effects of ground movement on higher floors. The increasing use of these technologies in both new and historic buildings highlights their growing importance in safeguarding structures against earthquakes.

1.1 Seismic isolation

Seismic isolation is a technique designed to mitigate the impact of seismic ground trembling on buildings and their components, thereby protecting them from damage. This technique involves using specialized devices to reduce the lateral movement, or drift, of structures during an earthquake. Seismic isolation is a fundamental concept in earthquake engineering, defined as the process of separating or decoupling a structure from its foundation. Essentially, it aims to reduce or avoid building damage during seismic activity. The idea of base isolation will be clarified in this essay using examples from other fields such as automobile suspension systems and boxing defence techniques. Additionally experiments and analytical graphs will be presented to illustrate the principles of base isolation. Seismic isolation systems include various types, such as steel-laminated rubber bearings and those with lead cores, as well as rubber and neoprene versions. Initially developed for bridge bearings, these systems have evolved into what are known as elastomeric bearings. These bearings, used as isolation devices for seismic waves, are created by vulcanizing thin steel plates with rubber plates. The more advanced versions, known as lead-laminated rubber bearings, consist of steel and rubber layers with a lead core embedded in the centre, offering highly effective seismic isolation.

1.2 Lead Rubber Bearings

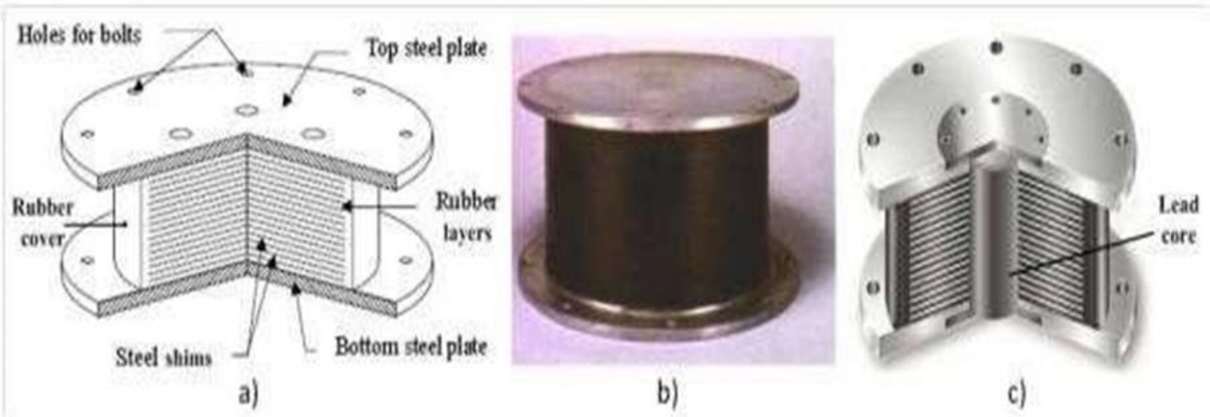


Figure No.1 Lead rubber bearing isolation.

Analyse the seismic behaviour of a G+12 building using the IS 1893:2002 code and the response spectrum method in ETABS. Evaluate the performance of the G+12 building with different base isolation systems, specifically rubber bearing isolation in seismic Zone V. Compare the seismic analysis results of buildings with various base isolation system against those of fixed-base buildings in different seismic zones. Identify the most effective and earthquake-resistant system based on analysis results, including joint displacements, shear, bending, torsion, base shear, and time period.

1.3 Objectives of the study

The primary objectives of this research are:

Analyse the seismic behaviour of a G+12 building using the IS 1893:2002 code and the response spectrum method in ETABS.

Evaluate the performance of the G+12 building in seismic Zone V—incorporating two types of RCC frames regular and irregular.

Compare the seismic performance of fixed-base buildings across seismic zone V with that of buildings equipped with lead rubber base isolation system. The comparison will focus on key parameters such as drift, shear forces, bending moments, torsion, frequency, and natural period to identify the most effective and earthquake-resistant system.

2 Literature reviews

Donato Cancellara and his team (2016) looked into how different isolation systems act under shaking, especially for multi-storey RC structures with a slightly asymmetrical form. They compared the effects of two isolation systems on the building in the event of an earthquake. They employed many metrics to examine the behaviour of an initial isolated building during tremors. Among the systems they looked at were the together with a Tension Slider (TS), a High Damping Rubber Bore (HDRB) is used. Lead Rubber Bearings (LRB) in conjunction with Friction Sliders (FS) constituted the other mechanism used. For the entire three-dimensional isolated structure, they conducted a dynamic nonlinear analysis. Then, they compared how both systems acted against the traditional fixed base structure. **Athanasios et al (2016)** simulated how hybrid base isolation systems respond during earthquakes. They investigated a system consisting of lightweight sliding bearings and high damping rubber bearings. Along with a linear viscous damper, they employed two models—bilinear and trilinear—to replicate the elevated damping rubber bearing. To investigate how the combined system responded to varied site conditions and tremors, they ran a number of numerical simulations. **Fabio De Angelis and his colleagues (2016)** dealt with ground vibrations coming from numerous directions while working on nonlinear dynamic simulations specifically for RC constructions that utilise hybrid base isolation systems. To protect building material from these ground disturbances, the researchers looked at three different hybrid base isolation methods. Combinations such as Lead Rubber Bearings with the friction Sliders, High Damping Rubber Capitals combined with Friction Sliders, also known and Elastomeric Spring Damps with Traction Sliders were examined. Important variables associated with these base unattached structures and the ones with fixed bases were compared, including base acceleration, compression effects, adjustments, inter-storey veers, and peak shear values. **N Murali Krishna et al (2016)** researched the nonlinear time history study of structures equipped with seismic safety measures. They used asymmetric buildings for this purpose to see how well they could manage seismic responses. They studied the long-term effects of shaking on structures with walls with shear and base isolation systems. A thorough linear time history examination (NLTHA) was performed on an RCC moment-resisting frame. The study examined elements such as structural displacements, torsional moments, and storey drifts. The results demonstrated that storey drift was significantly affected by base isolation use, shear forces & displacement for low-rise asymmetric buildings; meanwhile, shear walls had notable effects on high-rise asymmetric buildings. **Juan C. Ramallo** explored "Smart" base exclusion solutions for enhancing structural resilience. His research focused on advanced base isolation techniques incorporating smart materials and technologies to improve the performance of structures under seismic loads. Ramallo's study highlighted how these innovative solutions adapt to varying seismic conditions in real-time, offering significant improvements in mitigating earthquake-induced forces and vibrations. The findings provided insights into the effectiveness of smart base isolation systems, emphasizing their potential to enhance the safety and durability of structures subjected to dynamic loads. **J.C. Ramallo et al (2008)** conducted a seismic analysis. Their study compared the seismic performance of base isolated versus fixed base building systems. The research focused on evaluating how base isolation systems, which incorporate advanced technologies to absorb and dissipate seismic energy, perform in contrast to traditional fixed base systems. The findings indicated that base isolation significantly enhances the structural resilience of buildings by reducing seismic forces and displacements. This comparative analysis underscored the effectiveness of base isolation in improving safety and stability during earthquakes, providing valuable insights for engineers and designers in the field of earthquake engineering. **Tom W. Erickson and Arash Altoontash (2010)** delivered a presentation titled "Base Isolation for Manufacturing Organizations: Design & Construction Essentials". Their talk focused on the application of base isolation techniques specifically tailored for manufacturing facilities, highlighting key design and construction considerations. The presentation emphasized how base isolation can enhance the seismic resilience of manufacturing organizations by reducing the impact of earthquakes on critical infrastructure and operations. Erickson and Altoontash provided practical guidance on implementing base isolation systems, addressing challenges and best practices to ensure effective seismic protection. Their work offered valuable insights into adapting base isolation technologies for industrial settings, contributing to improved safety and operational continuity during seismic events. **Sonali Anilduke et al (2015)** presented a comparative analysis of buildings' seismic responses using base isolation methods. The study focused on evaluating the effectiveness of various base isolation techniques in mitigating seismic impacts on structures. Anilduke et al. assessed the performance of these methods by comparing their ability to reduce seismic forces and displacements in different building scenarios. Their findings highlighted the advantages of implementing base isolation systems, including improved structural safety and reduced damage during earthquakes. The research provided a comprehensive evaluation of different isolation strategies, offering valuable insights for optimizing earthquake-resistant design in building. **A. Swetha and Dr. H. Sudarsana Rao (2015)** conducted a non-linear simulation of a G+4 multistorey building using time history techniques, including Newmark's linear and average acceleration methods.

The study focused on evaluating the seismic response of the building through advanced simulation methods, providing a detailed analysis of how different time history techniques influence the performance predictions. Their research demonstrated the efficacy of these methods in capturing the complex dynamics of multistorey structures during seismic events, offering insights into their behaviour and response under earthquake loads. This work contributes valuable knowledge to the field of structural engineering, particularly in refining seismic analysis techniques and improving building safety. **S.D. Darshale and N.L. Shelke (2016)** examined "Seismic Response Control of RCC Framework Using Base Isolation." Their study focused on evaluating the effectiveness of base isolation systems in enhancing the seismic performance of reinforced concrete (RCC) frameworks. Dar shale and Shelke analysed how base isolation can mitigate the impact of seismic forces on RCC structures by reducing vibrations and displacements. The research demonstrated that base isolation significantly improves structural resilience, leading to better safety and reduced damage during earthquakes.

Their findings provided important insights into the implementation of base isolation techniques in RCC frameworks, offering guidance for engineers seeking to optimize seismic response control in structural design. **Minal Ashok Somwanshi (2015)** investigated the "Inelastic Behaviour of Steel Structures with Additional Viscoelastic Dampers." The study focused on analysing how viscoelastic dampers affect the inelastic response of steel structures under seismic loads. Somwanshi's research highlighted that incorporating these dampers significantly improves the energy dissipation capacity of steel frames, reducing structural deformations and enhancing overall stability during earthquakes. The findings demonstrated that viscoelastic dampers can effectively mitigate the inelastic behaviour of steel structures, providing valuable insights for designing more resilient and safer buildings in seismic-prone areas. **Dr. Manjunath N. Hegde et al (2016)** and his team published a comparative study on the seismic behaviour of buildings with fixed bases, base isolators, and shear walls. Their research aimed to assess and compare the effectiveness of these three seismic mitigation strategies.

The study demonstrated that base isolators significantly reduced seismic forces and displacements, offering superior performance compared to fixed bases. Shear walls also improved structural stability, though not as effectively as base isolation. The findings underscored the benefits of base isolation in enhancing building resilience during earthquakes, providing valuable insights for selecting appropriate seismic design strategies. **Lin and Shenton (1992)** compared the seismic resilience of fixed-base versus base-isolated steel frames.

Their analysis, involving both theoretical and numerical approaches, demonstrated that base-isolated frames performed significantly better under seismic loads than fixed-base frames. The base isolation system effectively reduced structural damage and mitigated the forces transmitted to the frame during earthquakes. The study underscored the benefits of incorporating base isolation to enhance the earthquake resilience of steel structures, offering valuable insights for improving structural safety and design practices in seismically active regions.

3.Methodology used

Response spectrum analysis, often referred to as linear dynamic statistical analysis is typically conducted using seismic codes. For this study, we use IS 1893:2016 (Part 1) for seismic analysis. Values for soil type and seismic zone parameters are obtained from the table provided in IS 1893:2016. For this analysis, a damping ratio of 5% is typically assumed Plotted. below is the range of responses graph for small soil conditions, which illustrates the correlation between the electromagnetic acceleration coefficient (Sa/g) and the time period.

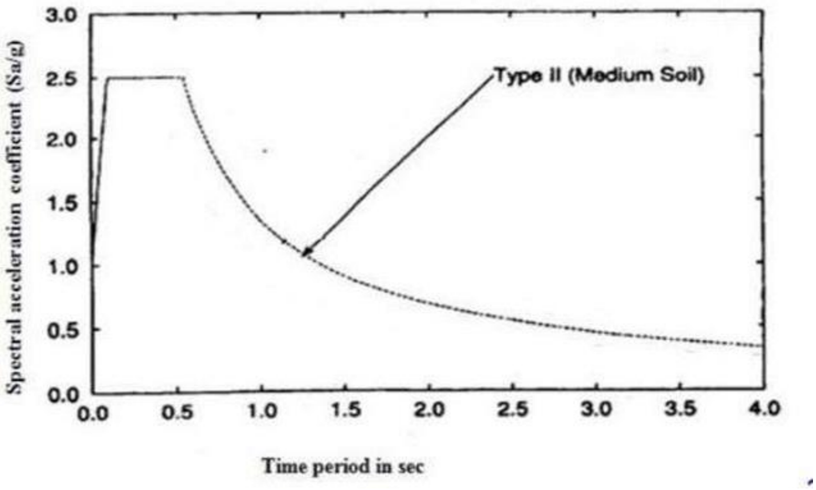


Figure No.2 Response range for 5% damping in medium-type soil

In order to evaluate the impact of powers on the structure, we must first ascertain the magnitudes of powers like X, Y, and Z.

The methods of combination that are employed consist of:

1. Peak values are absolute. summed up.

2. The amount of square squared (SRSS) - This method combines the squares of the peak values.

3. Complete Quadratic Combination - An enhancement of SRSS for modes that are tightly spaced.

When we examine ground motions, responses from spectrum analysis results deviate significantly from the findings of linear dynamic analysis. This response analysis frequently produces inaccurate results when an object or building is tall or uneven. This means that we need to consider different approaches, such as dynamic or non-linear static analysis.

For my research, I primarily examined the response of a medium-sized, regularly-structured building to seismic loading scenarios. I examined a multi-story G+12 skyscraper as part of my research. I used the ETABS Software to make a three-dimensional visualisation of the building in order to accomplish this.

3.1 Specifications considered for the analysis are

1.	Building use	: Residential
2.	Number of stories	: 12 floors
3.	Total height of building	: 36 m
4.	Shape of building	: Rectangular
5.	Geometric details	
a.	Ground floor height	: 3 m
b.	Each floor height	: 3 m
6.	Material info	
7.	Concrete Grade	: M30 (Columns & Beams)
8.	Steel	: HYSD 415
9.	Soil bearing capacity	: 200 kN/m2
10.	Construction type	: RCC

11. Column dimensions : 0.6m × 0.23 m

12. Beam dimensions : 0.45m × 0.23 m

13. Slab thickness : 0.150 m

14. Live load : 2.5 kN/m2 (IS:875:1987)

15. Density of Reinforced concrete: 25 kN/m3

16. Site type : v

17. Importance factor : 1.0

18. Response reduction factor :3

19. Damping Ratio : 5%

20. Structural class : C

21. Wind design code : IS 875-2015

22. RCC design code : IS 456:2000

23. Design code for steel : IS 800: 2007

24. Earthquake design code : IS 1893: 2016

3.2Building models in ETABS Software

The building models developed using ETABS software for different support systems arepresented in fig

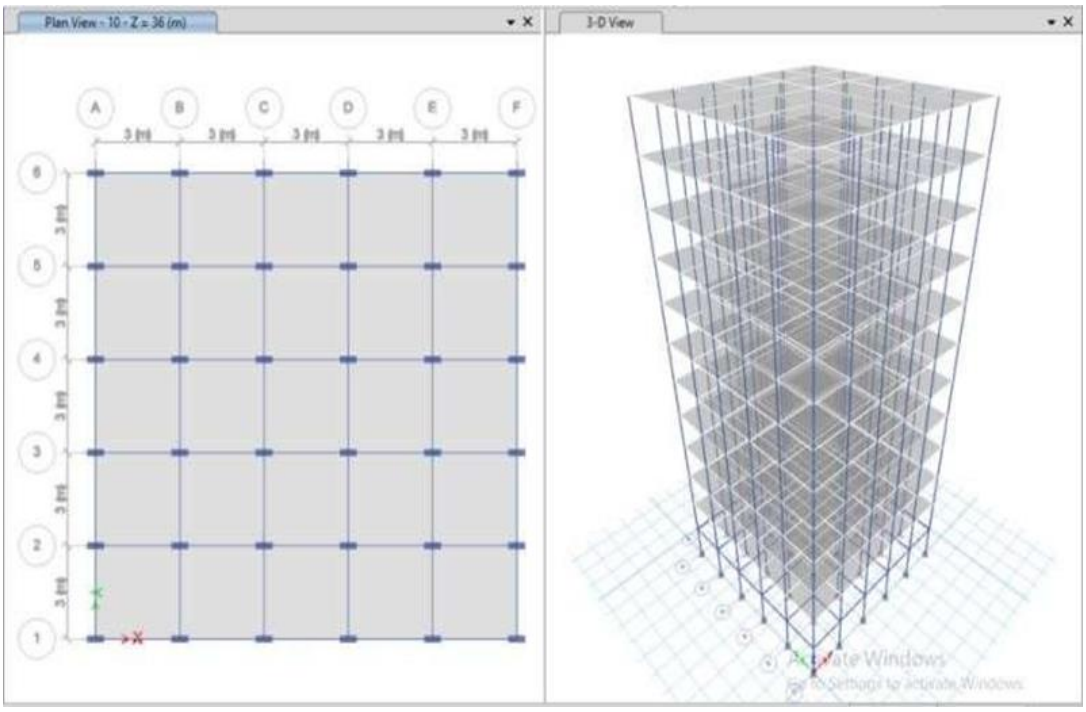


Figure No.3 Building Model with fixed supports

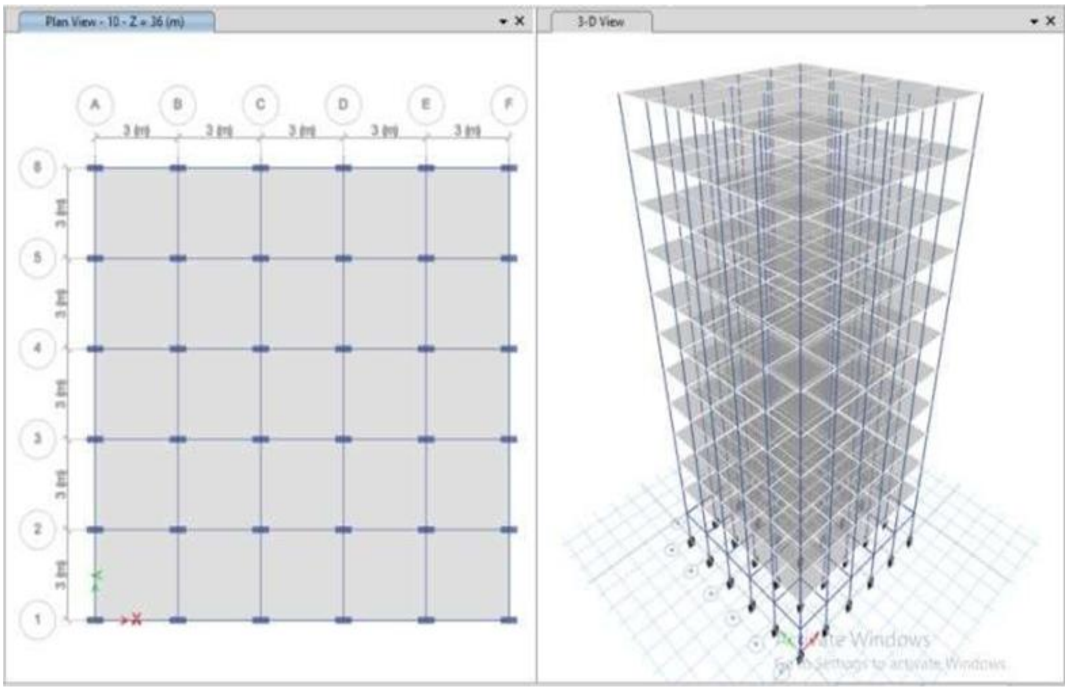


Figure No.4 Building Model with lead rubber base at support

4 Results and analysis RSA X

4.1 Drift X

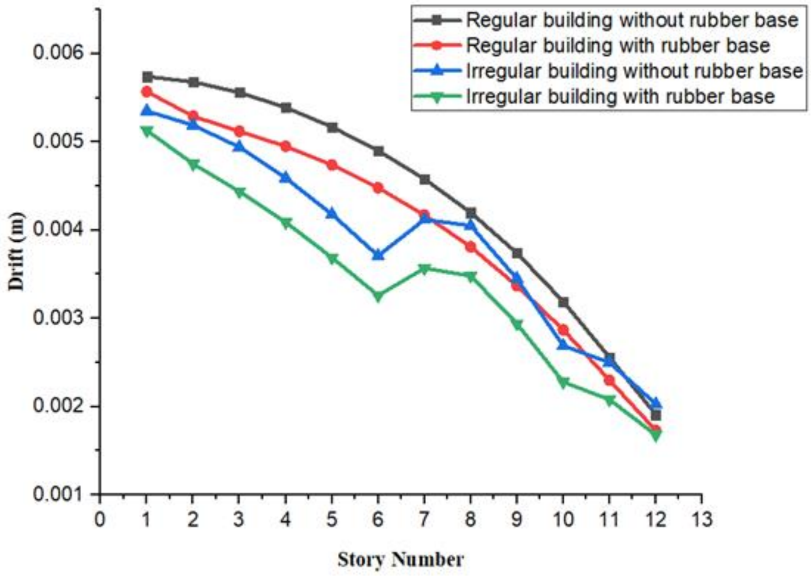


Figure No.5 Comparison of Drift Values due to RSA X

The Rubber base isolation system building in zone V was found to have fewer values when compared to fixed base in both regular and irregular models. The storey drift values resulting from the RSA X are depicted in the upper graph (fig. 5). In zone V condition, the intensity of seismic load is decreasing due to the rubber base isolation features by improving energy dissipation, enhancing overall seismic performance. For each storey number, irregular buildings generally have higher values than regular buildings. This indicates that irregular buildings might experience higher forces or drift, possibly due to their less predictable structural responses. Buildings with a rubber base generally show lower values compared to those without one. The rubber base likely helps in reducing the impact of seismic forces or vibrations, leading to lower values in the measurements.

4.2 Bending moment

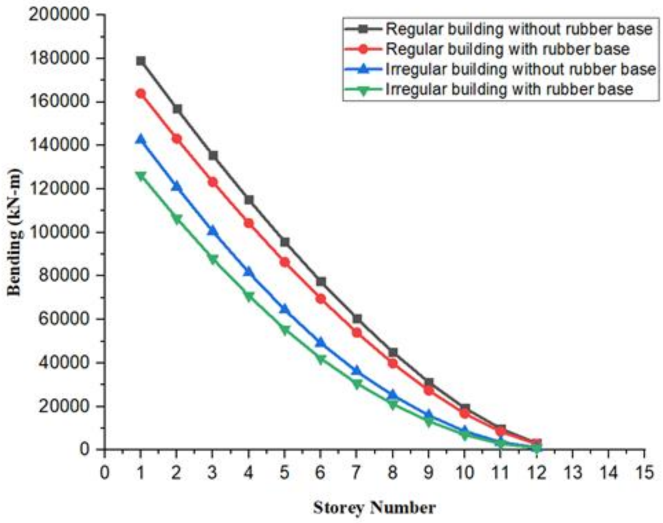


Figure No.6 Comparison of bending Values due to RSA X

The rubber base isolation system building in zone V was found to have fewer values when compared to other construction models in both regular and irregular frames. The above graph illustrates the variance of Comparison of bending values due to RSA X case. When comparingthe rubber base isolation system to fixed base isolation, the bending resistance is higher, as lead rubber base are designed to absorb and dissipate seismic energy, thereby reducing the forces transmitted to the building which is why the bending values are found as being less.

4.3 Shear Values

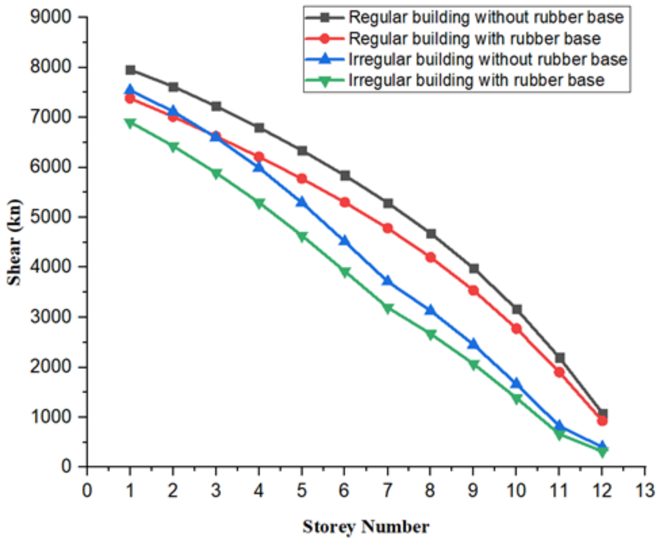


Figure No.7 Comparison of Shear Values due to RSA X

The rubber base isolation system building in zone V was found to have fewer values when compared to other building models. The above graph (fig.7)illustrates the variance of Comparison of Shear Values due to RSA X case. When comparing the rubber base isolation system to fixed base isolation, the shear resistance is higher, which is why the shear value is lower because the lead rubber base enhances energy dissipation and reduces the seismic forces transmitted to the structure, resulting in lower shear resistance requirements compared to fixed base isolation systems.

4.4 Torsion

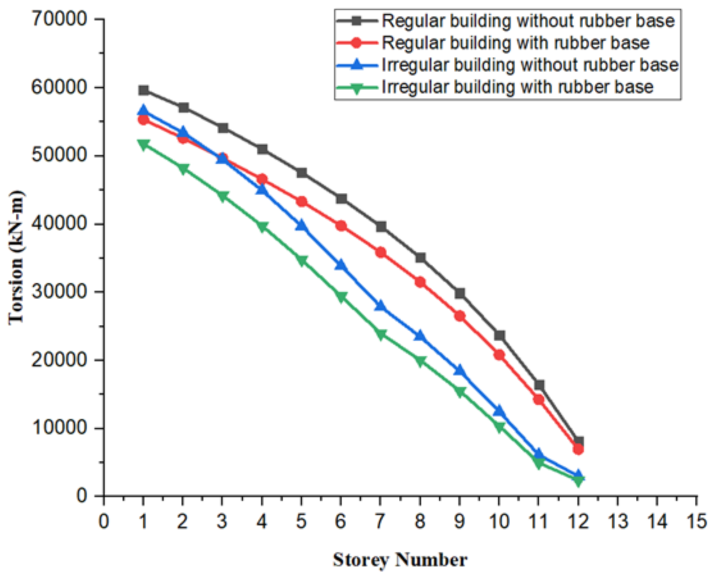


Figure No.8 Comparison of Torsion due to RSA X

Both regular and irregular frames the building constructed with a rubber base isolation system in zone V was found to have fewer values when compared to other building types. The abovegraph (fig. 8) illustrates the variance of Comparison of Torsion due to RSA X situation. When comparing the rubber base isolation system to fixed base isolation, the torque resistance is higher, which explains the improvement of building's ability to absorb and dissipate seismic energy, thereby decreasing the effective torsion experienced compared to fixed base isolation systems.

4.5 Frequency

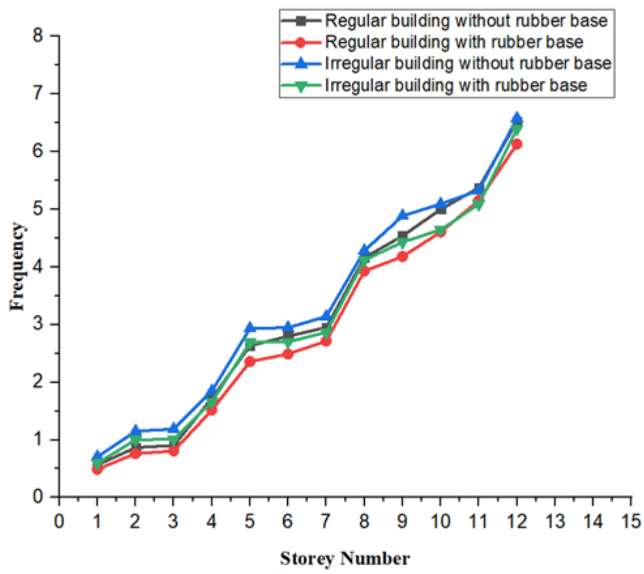


Figure No.9 Comparison of Frequency due to RSA X

In both regular and irregular, the structure constructed with a fixed base isolation system in zone V was found to have high values when compared to other building models. The above graph (fig. 9) illustrates the fluctuation of time period caused by the RSA X situation. In order to attain high frequency values for the fixed base system, the frequency intensity must be opposite to the time period.

4.6 Time period

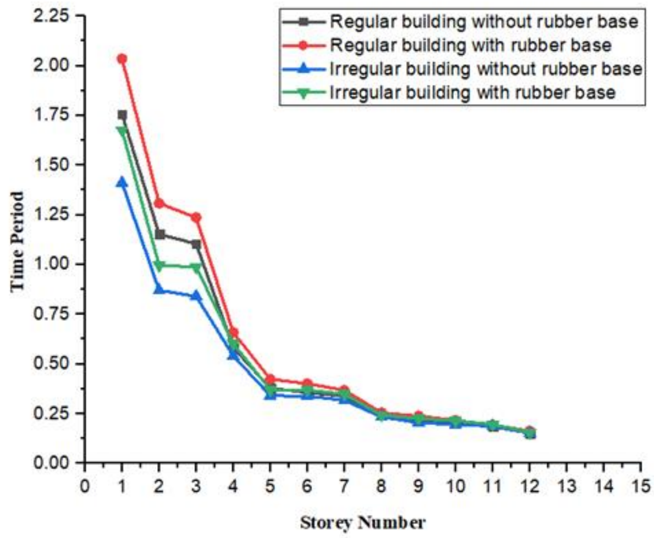


Figure No.10 Comparison of time period due to RSA X

The structure constructed with a fixed base isolation system in zone V was found to have lesser time period values when compared to other building types. The above graph (fig. 10) illustrates the fluctuation of time period caused by the RSA X .The model with lead rubber isolation takes longer to deflect the structure, The extended time period associated with the rubber base isolation system helps to reduce the overall seismic forces experienced by the building, improving its stability and performance during an earthquake.

5 RSA Y Results

5.1 Storey drift

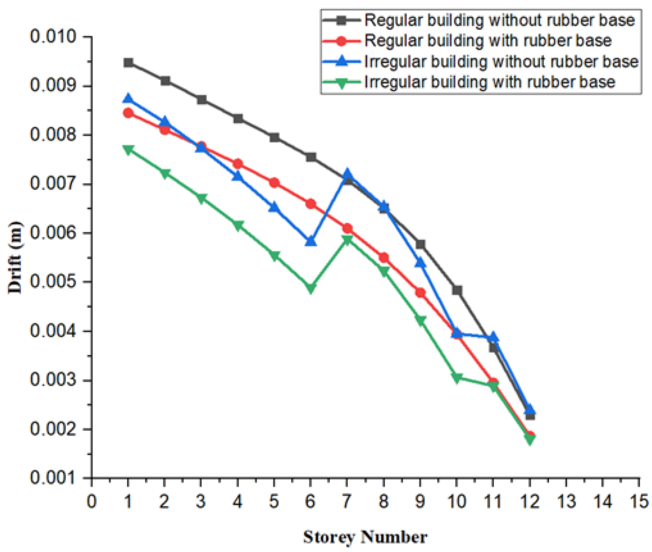


Figure No.11 Comparison of Drift Values due to RSA Y

The Rubber base isolation system building in zone V was found to have fewer values when compared to fixed base in both regular and irregular models. The storey drift values resulting from the RSA Y are depicted in the upper graph (fig. 11). In zone V condition, the intensity of seismic load is decreasing due to the rubber base isolation features by improving energy dissipation, enhancing overall seismic performance. For each storey number, irregular buildings generally have higher values than regular buildings. This indicates that irregular buildings might experience higher forces or drift, possibly due to their less predictable structural responses. Buildings with a rubber base generally show lower values compared to those without one. The rubber base likely helps in reducing the impact of seismic forces or vibrations, leading to lower values in the measurements.

5.2 Bending

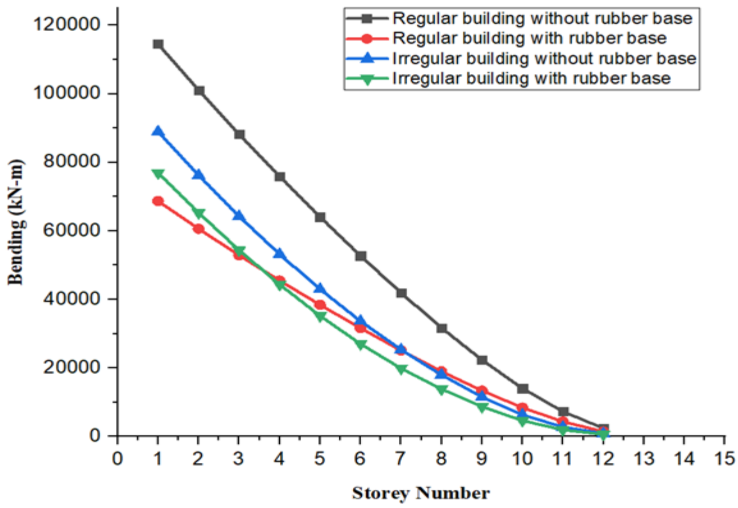


Figure No.12 Comparison of Bending due to RSA Y

The rubber base isolation system building in zone V was found to have fewer values when compared to other construction models in both regular and irregular frames. The above graph illustrates the variance of Comparison of bending values due to RSA Y case. When comparingthe rubber base isolation system to fixed base isolation, the bending resistance is higher. As lead rubber base isolation are designed to absorb and dissipate seismic energy, thereby reducing the forces transmitted to the building which is why the bending values are found as being less.

5.3 Shear

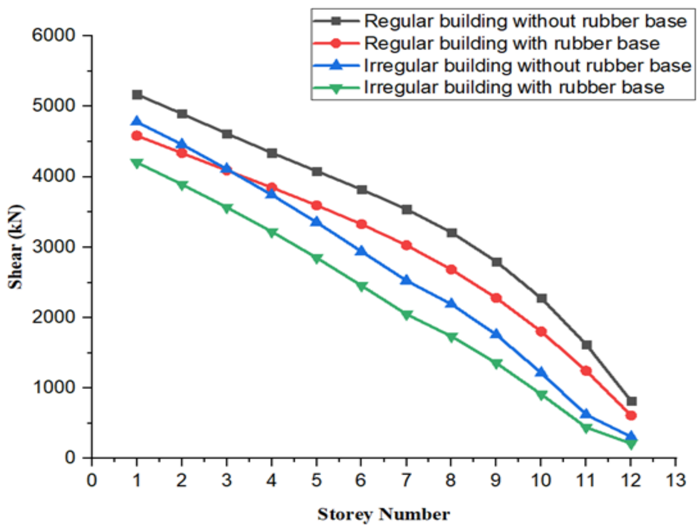


Figure No.13 Comparison of Shear due to RSA Y

The rubber base isolation system building in zone V was found to have fewer values when compared to other building models. The above graph (fig.13)illustrates the variance of Comparison of Shear Values due to RSA Y case. When comparing the rubber base isolation system to fixed base isolation, the shear resistance is higher, which is why the shear value is lower because the lead rubber base enhances energy dissipation and reduces the seismic forces transmitted to the structure, resulting in lower shear resistance requirements compared to fixed base isolation systems.

5.4 Torsion

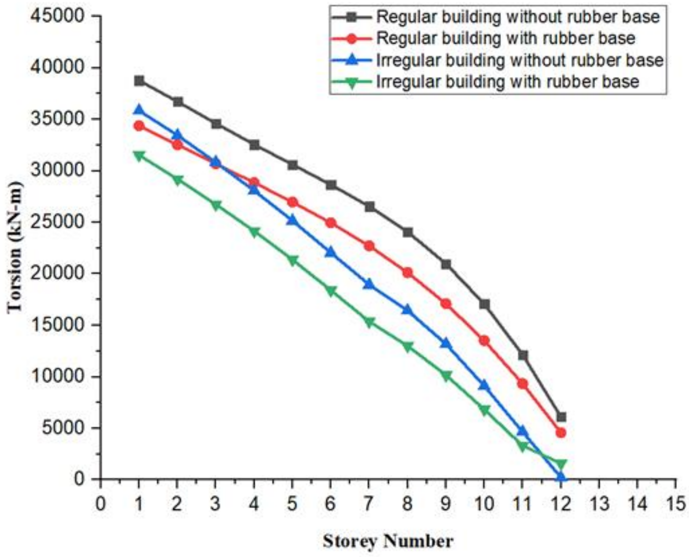


Figure No.14 Comparison of Torsion due to RSA Y

Both regular and irregular frames the building constructed with a rubber base isolation system in zone V was found to have fewer values when compared to other building types. The above graph (fig. 14) illustrates the variance of Comparison of Torsion due to RSA Y situation. When comparing the rubber base isolation system to fixed base isolation, the torque resistance is higher, which explains the improvement of building's ability to absorb and dissipate seismic energy, thereby decreasing the effective torsion experienced compared to fixed base isolation systems.

5.5 Frequency

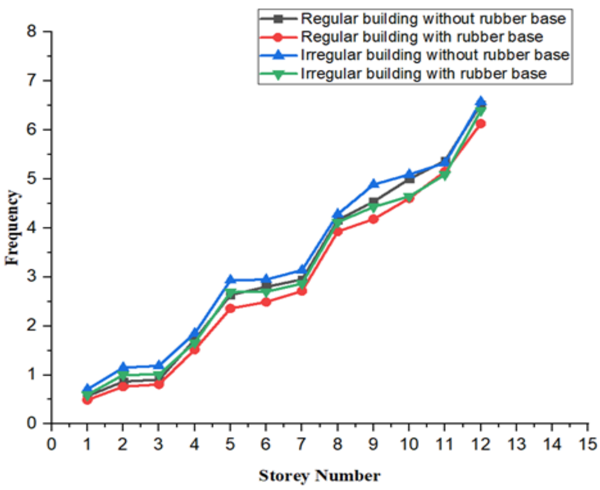
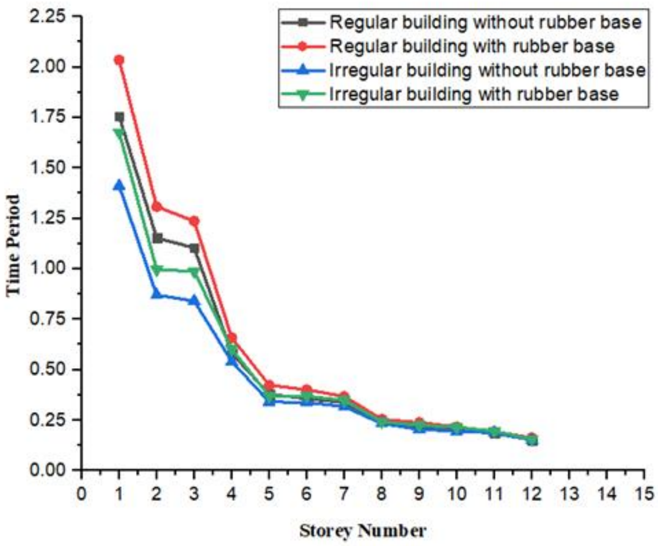


Figure No.15 Comparison of Frequency due to RSA Y

The structure constructed with a rubber base isolationsystem in zone V was found to have less values when compared to other building models in both regular and irregular frames. The above graph (fig. 15) illustrates the fluctuation of drift storey acceleration due to the RSA Y situation.In order to attain high frequency values for thelead rubber base isolation system, the frequency intensity must be opposite to the time period.

5.6 Time period



FigureNo.16 Comparison of Time period due to RSA Y

The structure constructed with a fixed base isolation system in zone V was found to have lesser time period values when compared to other building types. The above graph (fig. 16) illustrates the fluctuation of time period caused by the RSA X. The model with lead rubber isolation takes longer to deflect the structure, The extended time period associated with the rubber base isolation system helps to reduce the overall seismic forces experienced by the building, improving its stability and performance during an earthquake.

6. Conclusion

1. The analysis's findings show that base isolation technique is crucial for controlling building damages during seismic activity and for reducing seismic response when compared to fixed base buildings.
2. Fixed base isolation provides no energy dissipation, resulting in the full seismic forces being transmitted to the building but Lead rubber base isolation effectively absorbs and dissipates seismic energy through its viscoelastic properties and lead core, reducing the energy transmitted to the structure.
3. Lead rubber base isolation increases the time period of the building, leading to slower oscillations and reduced seismic forces whereas fixed base isolation results in a shorter time period, causing quicker and potentially more intense oscillations under seismic loads.
4. Fixed base isolation higher shear values as the full seismic forces are transmitted to the structure, leading to increased shear resistance but lead rubber base isolation lower shear values due to the base's energy-dissipating capabilities, reducing the demand on the building’s structural elements.
5. Lead Rubber Base Isolation reduces torsional effects and bending values by improving the building's energy absorption and distribution but fixed base isolation typically exhibits higher torsional responses and bending values due to less effective energy dissipation.
6. Fixed base isolation result in higher deflections and displacements as there is no additional damping or energy absorption mechanism whereas lead rubber base isolation manages deflection more effectively by absorbing seismic energy, resulting in controlled and lower displacements.

7. Lead Rubber Base Isolation enhances overall stability and performance during seismic events, providing better protection for the structure whereas fixed base isolation may lead to greater seismic impact on the building, potentially reducing its overall stability and performance.
8. Lead rubber base isolation is an effective strategy for mitigating the impact of earthquakes in seismic zones.
9. Rubber base isolation technologies improve the seismic performance of buildings by absorbing and dissipating seismic energy. This results in lower seismic forces transmitted to the structure, which in turn allows for a reduction in the amount of steel required for structural reinforcement. The benefits include not only cost savings but also more efficient and effective structural designs.

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