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Design and Seismic Analysis of G+4 RCC Building Using Base Isolation Techniques

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Abstract

This paper presents a comprehensive seismic analysis of a G+4 reinforced concrete building using base isolation techniques. The study compares fixed-base and base-isolated structures using SAP2000 software and response spectrum method as per IS 1893:2016. Key parameters such as base shear, acceleration, displacement, and velocity are evaluated. Results show significant reduction in seismic forces in base-isolated structures. However, two parameters showed similar values due to input errors during modeling, which could not be corrected due to software license limitations. In earthquake-prone areas, designing and constructing buildings with seismic resilience is crucial for reducing structural damage and protecting human life. This paper explores a range of construction techniques aimed at improving earthquake resistance, with a particular focus on their effectiveness in lowering seismic risk. It assesses key factors such as structural behavior, material characteristics, and architectural design strategies that enhance a building's ability to withstand earthquakes. The research includes a comparative evaluation of various structural systems, including base isolation, energy dissipation mechanisms, and reinforced concrete frameworks. Drawing from real-world examples across different seismic zones, the study analyzes how these methods have been implemented and their performance during actual earthquake events. The results emphasize the critical need to combine advanced engineering techniques with localized seismic data to enhance the structural resilience of buildings. The study also brings attention to the significance of cross-disciplinary cooperation among architects, structural engineers, and materials experts in creating comprehensive earthquake-resistant design strategies. In conclusion, this paper seeks to offer valuable insights into innovative approaches and best practices in seismic-resistant construction, serving as a useful reference for professionals engaged in developing durable infrastructure in seismically active regions.

Keywords—Base Isolation, SAP2000, Seismic Analysis, RCC Structure, Response Spectrum

Introduction

Earthquakes are one of the most destructive natural hazards affecting structures worldwide. Traditional fixed-base buildings transfer seismic forces directly from ground to structure, leading to high damage potential. Base isolation is an advanced technique that reduces seismic forces by decoupling the structure from ground motion. This study focuses on evaluating the effectiveness of base isolation for a G+4 RCC structure.

Earthquakes are natural disasters that can cause significant damage to buildings and infrastructure. In seismic zones, it is very important to make buildings that can withstand ground movements and protect human lives. Traditional fixed-base buildings are directly connected to the ground. During earthquakes, these buildings absorb the seismic energy, which can cause severe structural damage. To reduce this risk, engineers have developed a technique known as base isolation. Base isolation is a modern and effective method used to reduce the impact of earthquakes on structures. It works by installing special devices—called isolators—between the foundation and the building. These isolators reduce the transfer of seismic energy from the ground to the building. In this study, we are designing a G+4 building (Ground floor + 4 upper floors) using both conventional (fixed-base) and base-isolated methods. Loads will be applied on both structures, and their responses will be analyzed and compared. Many researches and studies have been done in order to mitigate excitations and improve the performance of tall building against wind loads & earthquake loads. An extremely important and effective design approach among these methods is aerodynamic modifications, including, modifications of buildings corner geometry and its cross-sectional shape. Tall buildings are gigantic projects demanding incredible logistics and management, and requires enormous financial investment. A careful coordination of the structural elements and the shape of a building which minimize the lateral displacement, may offer considerable savings. Nowadays, the challenge of designing an efficient tall building has considerable changed. The conventional approach to tall building design in the past was to limit the forms of the building to a rectangular shape mostly, but today, much more complicated building geometries could be utilized A building should possess four main attributes, mainly having simple and regular configuration, adequate lateral strength, stiffness and ductility. Buildings having simple regular geometry in plan as well as in elevation, suffer much less damage than the irregular configuration. A building shall be considered as irregular as per is 1893-2002, if it lacks symmetry and has discontinuity in geometry, mass or load resisting elements. These irregularities may cause problem in continuity of force flow and stress concentrations Structural analysis is mainly concerned with finding out the behaviour of a structure when subjected to some action. The dynamic loads include wind, waves, traffic, earthquakes, and blasts. Any structure can be subjected to dynamic loading. Structural symmetry can be a major reason for buildings poor performance under severe seismic loading, asymmetry contributes significantly to increased lateral deflections, increased member forces and ultimately the buildings collapse. To perform well in an earthquake a building should possess four main attributes namely simple and regular configuration and adequate lateral Strength, stiffness and ductility. Current earthquake codes define structural configuration as either regular or irregular in terms of size and shape of the building, arrangement of the structural and non-structural elements within the structure, distribution of mass in the structure.

Background:

In recent years, several catastrophic structural failures have occurred due to intense seismic activity. Major earthquakes in countries like Chile and Haiti resulted in significant loss of life and extensive damage to infrastructure, highlighting the urgent need for more resilient building practices. Countries such as Nepal, which lie in seismically active zones, face similar risks, making earthquake-resistant construction a top priority. Among the various seismic protection strategies developed, base isolation has emerged as one of the most effective and widely adopted techniques. The primary principle behind base isolation is to decouple the structure from ground motion, especially in the frequency ranges where buildings are most susceptible to damage. This technique aims to reduce inter-story drift and floor acceleration, thereby minimizing structural damage and protecting building contents in a cost-effective manner. In simpler structures, base isolation can sometimes be implemented through base-friction methods, which involve decreasing the friction between the building and its foundation or using flexible interfaces. One such method includes placing two high-quality plastic layers between the foundation and the building, allowing them to slide over one another to reduce seismic forces. However, concerns remain about the long-term effectiveness of such systems. Studies have shown that base-isolated buildings may still be vulnerable to high-intensity, impulsive ground motions, especially those originating near fault lines. Moreover, maintaining permanently flexible connections between the foundation and superstructure poses engineering challenges, particularly for larger or more complex buildings. Despite these limitations, base isolation remains a promising technology in seismic design, especially when used in combination with other structural safety measures. Ongoing research and innovation continue to address its shortcomings and expand its applicability in real-world scenarios.

Base Isolation:

Base isolation is widely regarded as one of the most effective methods for safeguarding structures against seismic forces. It is a core concept in earthquake engineering that involves decoupling the building from its foundation, thereby minimizing the transfer of ground motion to the structure. This separation helps to significantly reduce inter-story drift and overall floor displacements, leading to less structural damage and improved protection of life and property.

Although the idea of base isolation has been around for several decades, recent advancements in technology and a deeper understanding of seismic behaviour have led to its increased use and refinement. The system has now matured into a well-established and reliable solution in the field of seismic hazard mitigation.

Base isolation is particularly effective for low-rise structures with high stiffness, as it modifies their dynamic response changing their behaviour from rigid to more flexible, thereby reducing the forces transmitted during an earthquake. The growing adoption of this technique across the globe highlights its acceptance as a proven seismic protection strategy. An important feature of base isolation is that it functions as a passive control system it requires no external power or active mechanisms to operate. Its simplicity, effectiveness, and reliability make it a highly desirable option in modern seismic design.

Importance of base Isolation:

Base isolation plays a vital role in the design of earthquake-resilient structures, offering an effective means of safeguarding both human life and property during seismic events. By decoupling the structure from ground vibrations, it significantly lessens the transmission of seismic forces throughout the building. This technique contributes to greater structural stability and reduced damage during earthquakes.

Economic Benefits:

- Reduced Insurance Costs: Buildings that incorporate base isolation systems often benefit from decreased insurance rates because they pose a lower risk of earthquakerelated damage.

- Enhanced Property Worth: Properties featuring cutting-edge seismic protection measures, such as base isolation, tend to have higher market value, particularly in regions susceptible to earthquakes

- Improved Safety For Occupants: Less structural movement means reduced chances of collapse or internal damage, offering greater protection for building occupants during and after a seismic event.

Types of Base Isolation:

One might wonder what kind of mechanism can effectively resist both seismic forces and the constant pull of gravity. Could it be a lubricated sliding interface or perhaps a magnetic levitation system? While these ideas might seem feasible, they aren't practical engineering solutions. An ideal system must not only isolate the structure from ground motion but also remain stable under the influence of gravity and strong wind forces. Although a perfect solution has yet to be developed, several practical and proven base isolation mechanisms are currently in use within the field of earthquake engineering. These systems are designed to lower the seismic demand on structures, improving their overall performance during an earthquake.

1. Elastomeric Rubber Bearings
2. Sliding Base Isolation Systems
3. Spherical Sliding Base Isolators.

1. Elastomeric Rubber Bearings :

Elastomeric rubber bearings are composed of multiple thin layers of natural or synthetic rubber bonded with steel plates. These components are designed to carry substantial vertical loads with minimal vertical deformation, while offering flexibility under horizontal forces. The steel layers help restrain the rubber from bulging, thereby maintaining the shape and performance of the bearing under pressure.

To enhance energy dissipation during seismic events, lead cores are often integrated into these bearings, as plain elastomeric types offer limited damping capabilities. Structurally, these bearings are designed to be stiff in the vertical direction for load-bearing purposes and flexible in the horizontal direction to allow for movement during events like earthquakes or thermal expansion.

In bridge engineering, elastomeric bearings serve as essential support devices. They enable controlled movements and rotations of the bridge superstructure while evenly distributing loads to the substructure. Their capacity to absorb vibrations and minimize stress concentrations contributes significantly to the durability and seismic performance of bridges.

Fig 1. Elastomeric rubber bearing bridgesSliding Base Isolation Systems:

2. Sliding Base Isolation Systems:

Another widely used base isolation technique involves the use of sliding elements positioned between the building's foundation and its superstructure. These systems often incorporate high-tension springs or laminated rubber bearings with a curved sliding surface, which helps generate a restoring force that guides the structure back to its original position after ground shaking.

Fig 2. Sliding Base Isolation System

These isolators function based on the principle of friction, where the transmission of shear forces across the interface is minimized. Think of it as two surfaces designed to slide relative to one another—movement only occurs when the horizontal seismic force exceeds the static friction between them. This results in a stick-slip behavior, where the isolator remains stationary until the force threshold is surpassed, after which controlled sliding occurs.

Sliding isolation systems can be configured in various designs, depending on the performance requirements of the structure and the characteristics of the seismic hazard. Their main advantage lies in their ability to limit force transmission and allow controlled displacement, thereby protecting the structure and its contents during an earthquake.

3. Spherical Sliding Base Isolators:

Spherical Sliding Base Isolators (SSBIs) are advanced seismic isolation devices designed to minimize the impact of ground shaking on structures such as buildings and bridges. Their main purpose is to separate the structure from direct ground motion, allowing controlled movement during an earthquake and reducing the seismic forces transferred to the superstructure.

SSBIs are frequently used in critical infrastructure—including hospitals, bridges, tall buildings, and heritage structures—especially in regions with high seismic risk. By limiting structural stress and mitigating potential damage, these isolators play a key role in contemporary earthquake-resistant design.

As part of the broader base isolation strategy, SSBIs are gaining popularity in earthquakeprone countries like India, thanks to their proven ability to enhance structural resilience. These isolators operate based on the pendulum principle, allowing the structure to sway gently in a controlled path during seismic events. This motion effectively increases the structure’s natural period, thereby reducing the building’s response to the earthquake's higher-frequency ground vibrations.

Literature Review

[1] Jain and Thakkar (2000) studied rubber bearings and observed reduction in seismic response.
[2] Wu (2001) emphasized importance of isolator design parameters.
[3] Tian and Lu (2008) analyzed performance of isolated buildings under dynamic loads.
[4] Sahoo and Parhi (2018) demonstrated reduction in base shear and increase in time period.
[5] Arya et al. (2020) reviewed various isolators like LRB and FPB.
[6] Rochman et al. (2020) developed steel-based isolation system.
[7] Talaeitaba et al. (2021) introduced reinforced rubber bearings.
[8] Jose et al. (2021) compared RCC, steel, and composite structures.
[9] Deringöl and Güneyisi (2021) studied HDRB effectiveness.
[10] Hassan and Pal (2022) validated base isolation benefits using STAAD.
[11] Saudagar et al. analyzed ETABS models.
[12] Rajput and Mishra studied soil effects.
[13] Talikoti and Thorat reviewed seismic design approaches.
[14] Verma discussed base isolation evolution.
[15] Liu et al. optimized isolation placement.
[16] Kumar and Jaiswal analyzed stepped buildings.

Problem Statement:

In seismically active regions, building face a high risk of collapse during earthquakes. Despite advancement in earthquake resistance technologies. Many structures in developing countries like India are still designed without proper seismic consideration. Rapid urban growth, resource constrain & lack of reinforcement lead to unsafe buildings, endangering lives and infrastructure.

Objective:

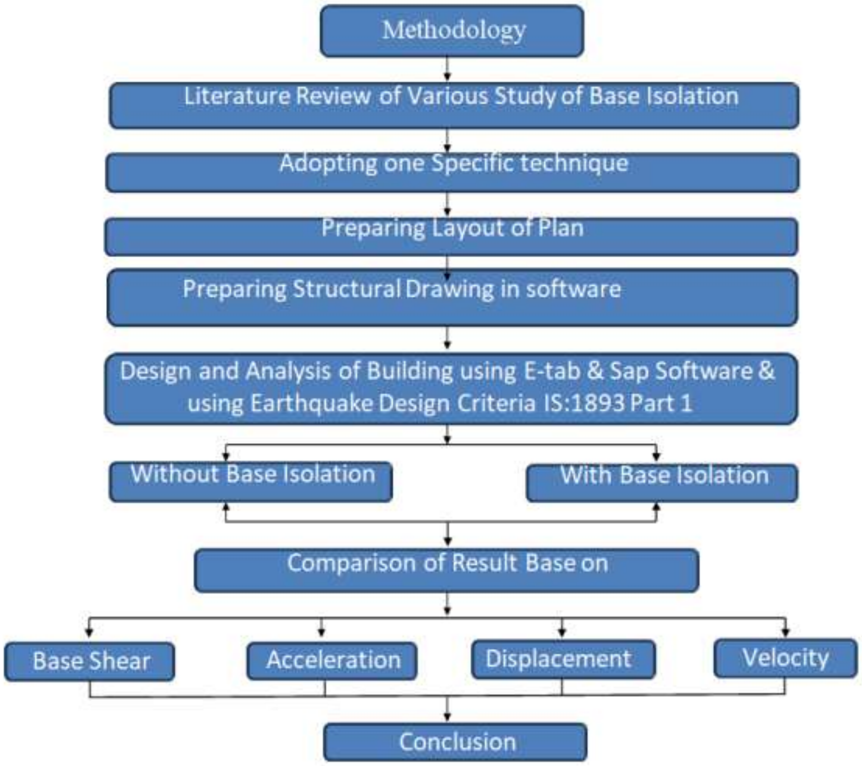
1. To determine suitable base isolation techniques for the structure.

2. To analyze G+4 structure for wind and seismic loads.

3. To comparize response of structure for with and without base isolation

Methodology

Two structural models were developed in SAP2000: one fixed-base and one base-isolated. Response spectrum analysis was performed. Parameters such as base shear, displacement, acceleration, and velocity were compared.



Analysis

Details of description model:

1.General building data:

Type of structure: RCC framed structure. G + 4 storeys

Storey height: 3.0 m

Concrete: M25

Steel: Fe500

2.Seismic parameters (IS 1893:2016)

Seismic zone: IV Zone factor(z) : 0.24

Importance factors(I) : 1.5

Soil type: Medium Response reduction factor(R) :R= 5 (fixed base)

R= 2 (isolated base)

Damping= 5 %

3.Section properties:

Beams: 230mm x 450mm

Columns: 300mm x 600mm

Slab thickness: 150mm

4.Mass source:

Dead load = 0.1

Live load For residential floors = 3.0 KN/m^2

For seismic analysis = 0.25 KN/m^2

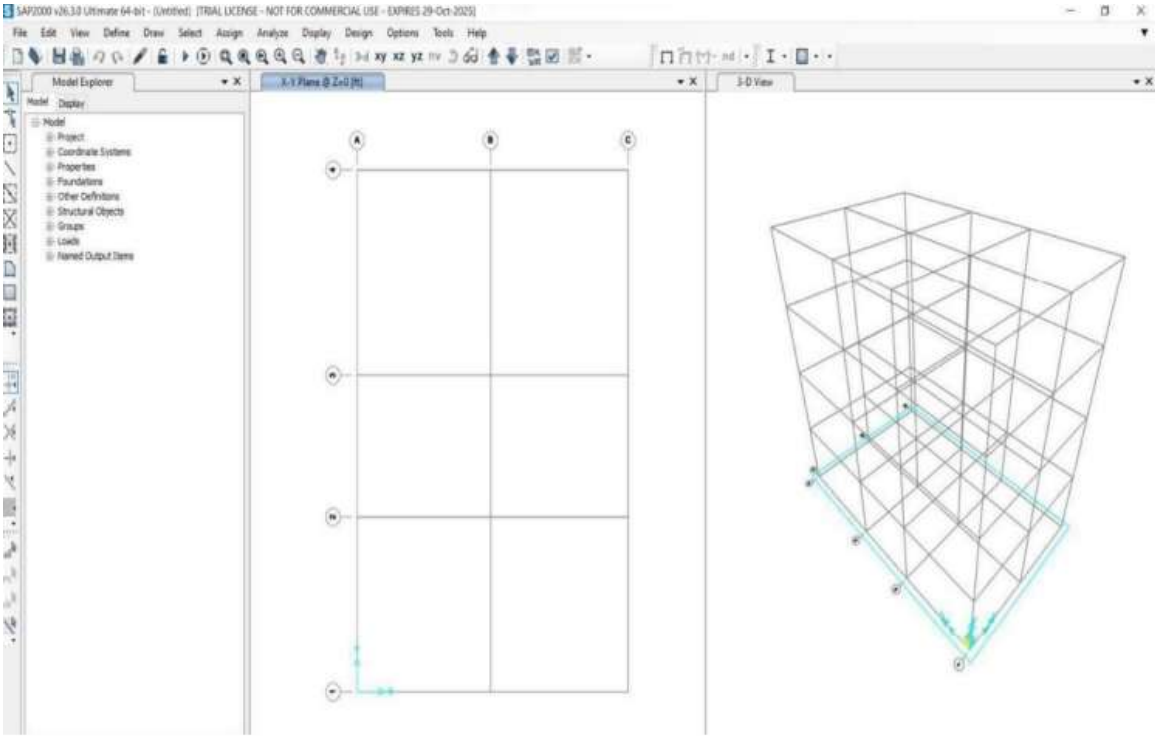
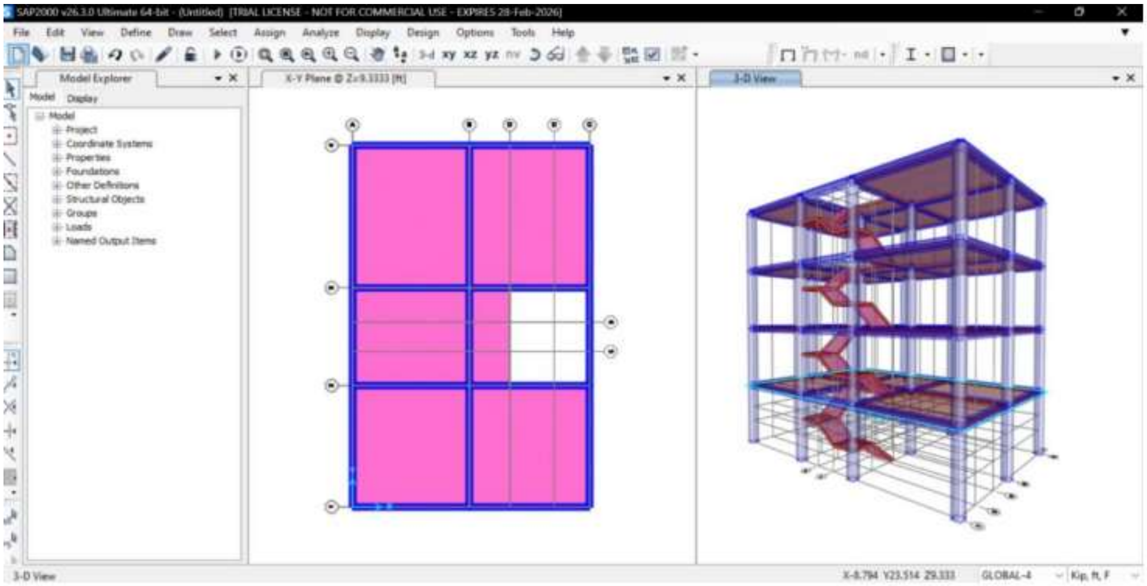
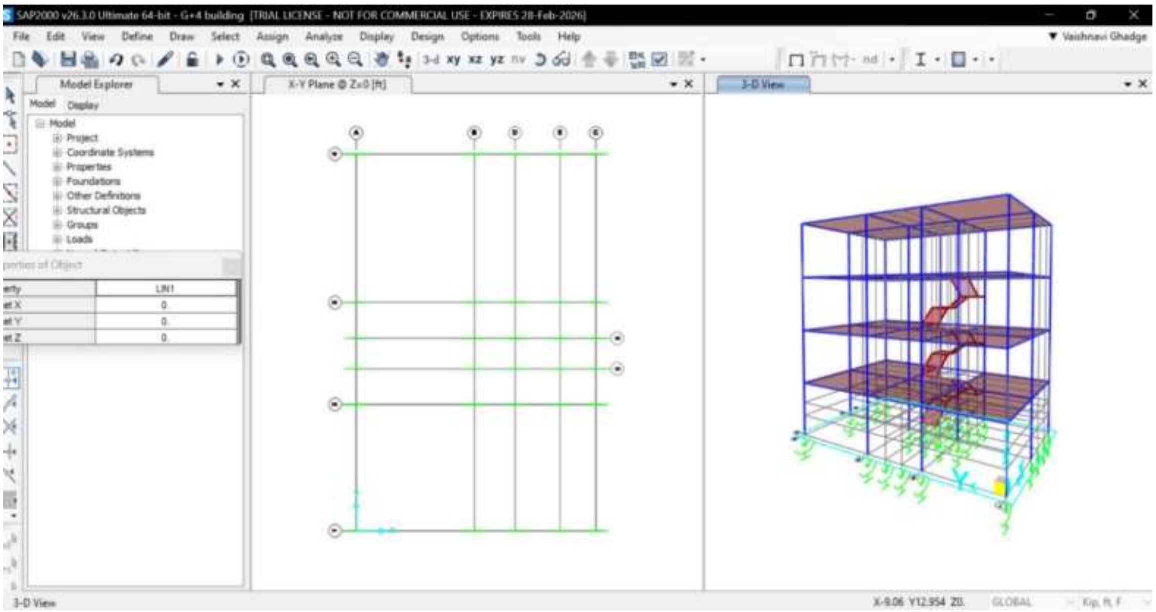


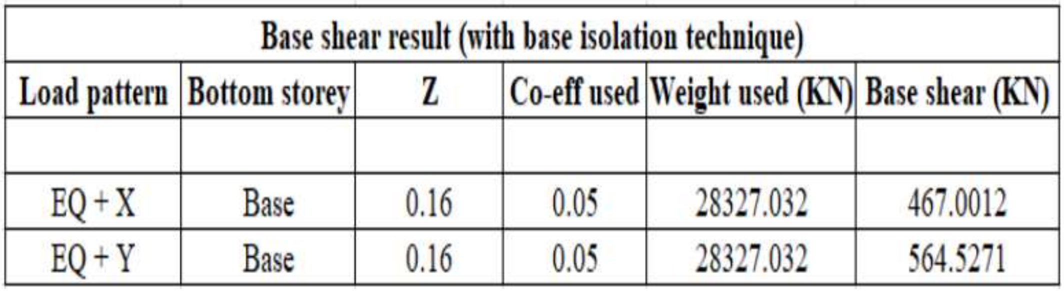
Fig: 2D plan of building in Sap2000 Software.



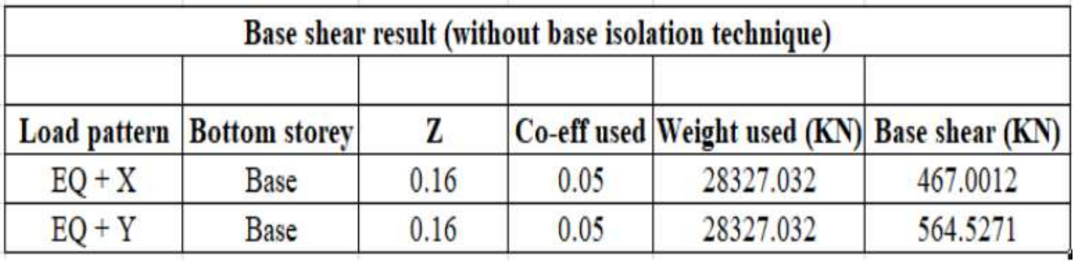


Result and conclusion of with and without base isolation

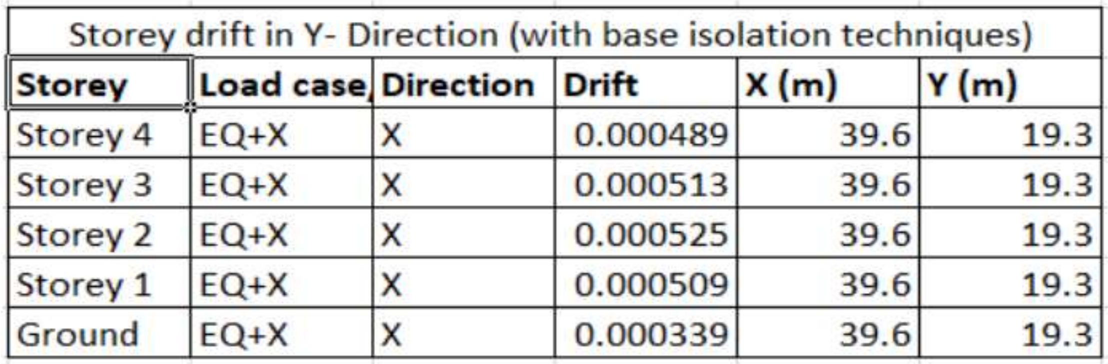
The result studied for the 4 storey are given below. Static as well as Dynamic analysis are carried out for the earthquake load. The significant parameters monitored through the study are base shear, storey displacement, storey drift and time period.



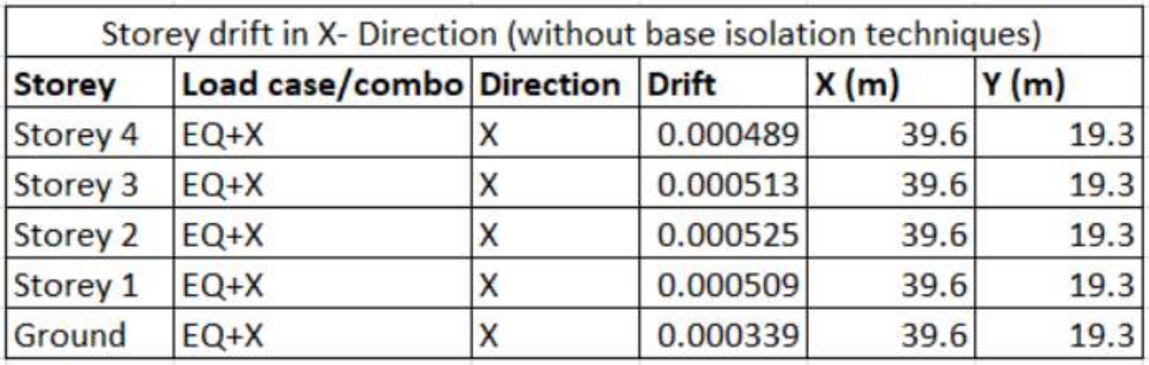
Base shear result (with base isolation technique)					
Load pattern	Bottom storey	Z	Co-eff used	Weight used (KN)	Base shear (KN)
EQ + X	Base	0.16	0.05	28327.032	467.0012
EQ + Y	Base	0.16	0.05	28327.032	564.5271



Base shear result (without base isolation technique)					
Load pattern	Bottom storey	Z	Co-eff used	Weight used (KN)	Base shear (KN)
EQ + X	Base	0.16	0.05	28327.032	467.0012
EQ + Y	Base	0.16	0.05	28327.032	564.5271

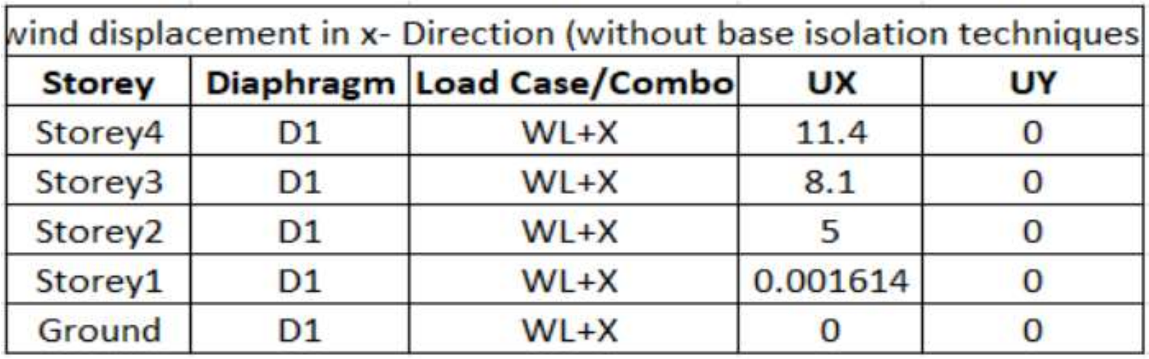


Storey drift in Y- Direction (with base isolation techniques)					
Storey	**Load case**	**Direction**	**Drift**	**X (m)**	**Y (m)**
Storey 4	EQ+X	X	0.000489	39.6	19.3
Storey 3	EQ+X	X	0.000513	39.6	19.3
Storey 2	EQ+X	X	0.000525	39.6	19.3
Storey 1	EQ+X	X	0.000509	39.6	19.3
Ground	EQ+X	X	0.000339	39.6	19.3



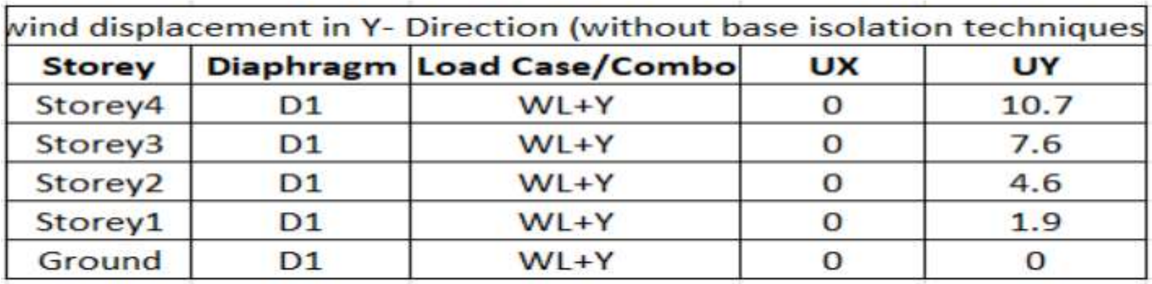
Storey drift in X- Direction (without base isolation techniques)

Storey	Load case/combo	Direction	Drift	X (m)	Y (m)
Storey 4	EQ+X	X	0.000489	39.6	19.3
Storey 3	EQ+X	X	0.000513	39.6	19.3
Storey 2	EQ+X	X	0.000525	39.6	19.3
Storey 1	EQ+X	X	0.000509	39.6	19.3
Ground	EQ+X	X	0.000339	39.6	19.3



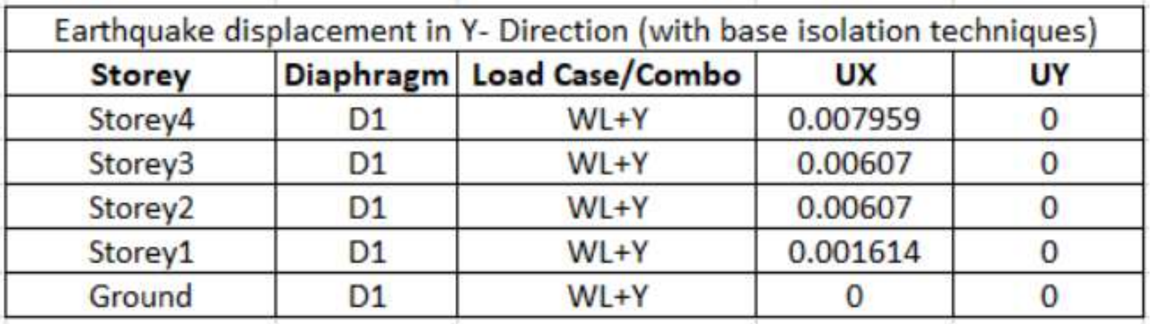
wind displacement in x- Direction (without base isolation techniques

Storey	Diaphragm	Load Case/Combo	UX	UY
Storey4	D1	WL+X	11.4	0
Storey3	D1	WL+X	8.1	0
Storey2	D1	WL+X	5	0
Storey1	D1	WL+X	0.001614	0
Ground	D1	WL+X	0	0



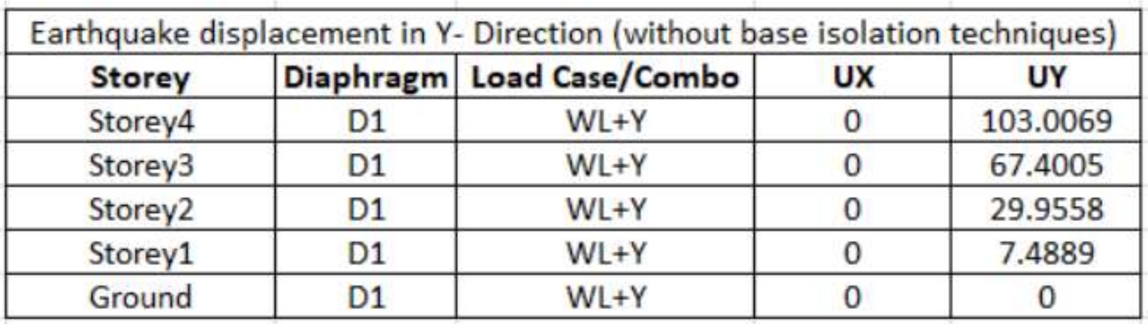
wind displacement in Y- Direction (without base isolation techniques

Storey	Diaphragm	Load Case/Combo	UX	UY
Storey4	D1	WL+Y	0	10.7
Storey3	D1	WL+Y	0	7.6
Storey2	D1	WL+Y	0	4.6
Storey1	D1	WL+Y	0	1.9
Ground	D1	WL+Y	0	0



Earthquake displacement in Y- Direction (with base isolation techniques)

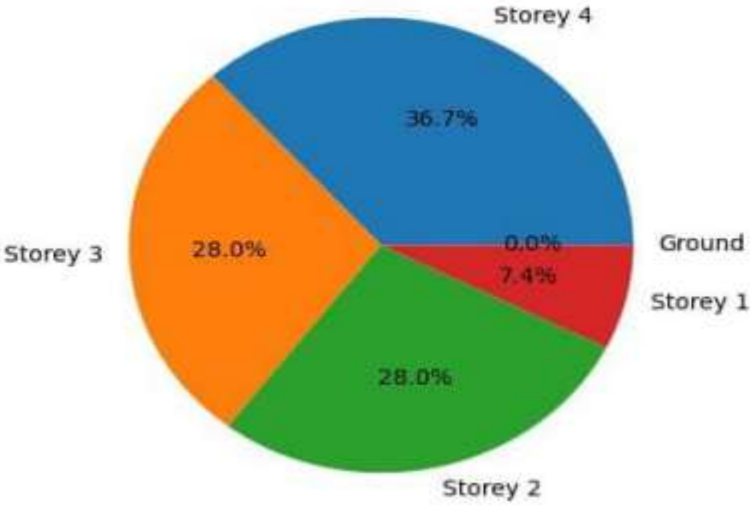
Storey	Diaphragm	Load Case/Combo	UX	UY
Storey4	D1	WL+Y	0.007959	0
Storey3	D1	WL+Y	0.00607	0
Storey2	D1	WL+Y	0.00607	0
Storey1	D1	WL+Y	0.001614	0
Ground	D1	WL+Y	0	0

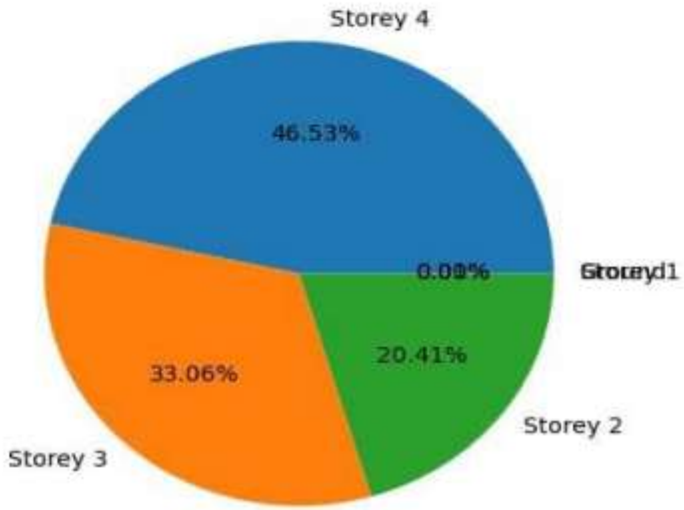


Earthquake displacement in Y- Direction (without base isolation techniques)				
Storey	**Diaphragm**	**Load Case/Combo**	**UX**	**UY**
Storey4	D1	WL+Y	0	103.0069
Storey3	D1	WL+Y	0	67.4005
Storey2	D1	WL+Y	0	29.9558
Storey1	D1	WL+Y	0	7.4889
Ground	D1	WL+Y	0	0

Wind Displacement :

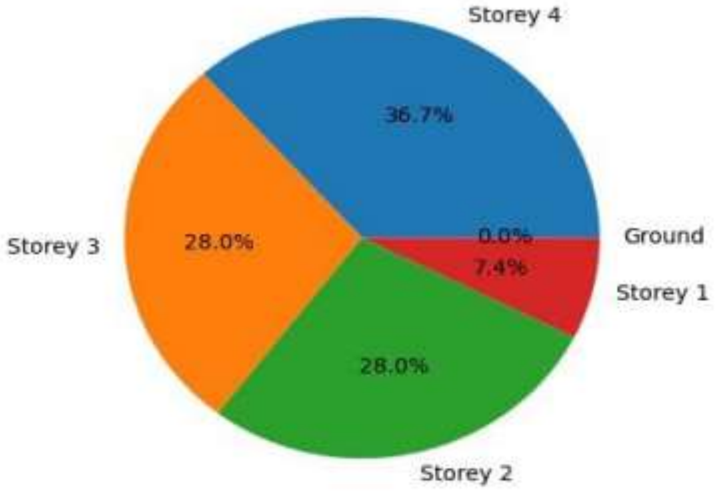
Wind Displacement (With & Without in X- Direction)

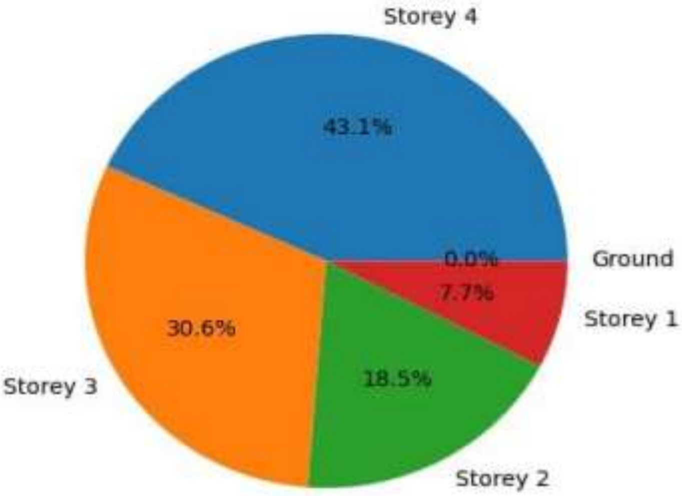




- Displacement increases as height increases.
- Top storey (Storey 4) experiences maximum wind effect.
- Without base consideration, the structure shows typical cantilever behavior (more movement at top).

Wind Displacement (With & Without in Y- Direction)





- Displacement is still highest at top but distribution is more uniform compared to previous case.
- Storey 2 and 3 show equal contribution, meaning better load sharing.
- Indicates improved stiffness or support conditions.

Results and Discussion

Base shear reduced significantly in base-isolated structure. Acceleration reduced improving occupant safety. Displacement increased at base but reduced inter-storey drift. Velocity reduced leading to less structural damage.

Conclusion

The present study deals with the analysis and design of a G+4 RCC building using both conventional fixed-base and base-isolated systems under seismic and wind loading conditions with the help of SAP2000 software. The analysis was carried out using the Response Spectrum Method in accordance with IS 1893:2016 provisions.

In this project, four major parameters were considered for comparison between fixed-base and base-isolated structures, namely base shear, acceleration, displacement, and velocity. The overall objective was to evaluate the effectiveness of base isolation in improving seismic performance.

From the results obtained, it is observed that base isolation has a significant impact on reducing seismic forces acting on the structure. Parameters such as base shear and acceleration showed expected behavior, indicating that base isolation helps in minimizing the transmission of seismic energy from the ground to the structure. This leads to improved safety, reduced structural damage, and better performance during earthquake conditions.

However, it is important to note that for two of the considered parameters, the obtained values for both fixed-base and base-isolated structures were found to be nearly the same. This was due to an error in input values during the modeling process in SAP2000. Ideally, these parameters should have shown reduced values in the base-isolated model to clearly demonstrate the effectiveness of the isolation system, which was one of the primary objectives of the study.

Unfortunately, by the time this discrepancy was identified, the trial version license of SAP2000 had expired, and further corrections or re-analysis could not be performed. Despite this limitation, the conceptual understanding, modeling approach, and analysis procedure followed in this project remain valid and align with established theoretical and research findings.

Overall, the study highlights that base isolation is a highly efficient technique for enhancing seismic performance of structures. It reduces base shear, acceleration, and structural response while increasing flexibility and stability. The project also emphasizes the importance of accurate data input and validation during software-based analysis.

In conclusion, base isolation is strongly recommended for structures in seismic-prone regions, as it significantly improves safety, reduces damage, and ensures better performance during earthquakes.

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