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ISSN 2249-3352 (P) 2278-0505 (E)
Cosmos Impact Factor-5.86

COMPARATIVE NON LINEAR TIME HISTORY ANALYSIS FOR G+ 15 BUILDING WITH AND WITHOUT BASE ISOLATOR

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Abstract *Base isolation, achieved through the installation of rubber bearings and energy-dissipating devices beneath the superstructure, enhances both structural and occupant safety, and is also applicable for retrofitting historic buildings. Unlike conventional seismic design, which relies on increased strength and ductility, base isolation reduces seismic loads by altering a structure's stiffness and damping characteristics. A G+15 storey building was analysed using the ETABS software in accordance with IS 1893:2016, considering both regular and irregular models in seismic Zones II and IV. The nonlinear time history analysis is compared with fixed base, partial isolation(Fixed support and Lead rubber bearing), and full isolation systems (Lead rubber bearing)with respect to seismic parameters such as joint displacement, storey drift, and base shear. The Results are demonstrated that both partial and full base isolation significantly reduced base shear, storey displacement, and storey drift compared to fixed base models, confirming the effectiveness of base isolation in seismic performance improvement in both zones.*

Key word: *Base isolation, Nonlinear time history analysis, lead rubber bearing*

1. Introduction

Seismic isolation is an effective technique used to reduce the impact of earthquake ground motions on structures by introducing flexible and energy-dissipating elements at the base, such as rubber bearings or sliding devices. This method increases the structure's natural period and reduces acceleration and force demands on the superstructure. To accurately evaluate the performance of isolated structures under seismic loading, Nonlinear Time History Analysis (NLTHA) is commonly used. NLTHA simulates the detailed time-dependent response of a structure by considering the nonlinear behaviour of materials and isolation devices, allowing for precise assessment of displacement, force, and energy dissipation during earthquakes.

1.1 Principles of Base Isolation

1. Decouples the structure from ground shaking by introducing flexible isolators at the base, reducing seismic forces transmitted to the building.
2. Increases the natural period of the structure, shifting it away from the dominant earthquake frequencies, which lowers acceleration demand.
3. Dissipates seismic energy through hysteretic behaviour of isolators, reducing energy transmitted to the superstructure.
4. Limits structural deformation and damage by controlling lateral displacements, protecting both structural and non-structural component.

1.2 Types of Base Isolation Systems

Seismic isolation reduces earthquake forces on a structure by introducing flexibility and energy dissipation at the base. The most commonly used isolators are:

Elastomeric Rubber Bearings (ERB)

- Composed of alternating layers of rubber and steel plates.
- Very stiff vertically (supports high loads) but flexible laterally.
- Variants:

a) **LDRB:** Low Damping Rubber Bearing
b) **HDRB:** High Damping Rubber Bearing

Lead-Rubber Bearings (LRB)

- Similar to ERB but with a lead core.
- Lead provides additional energy dissipation through shear deformation, improving damping.

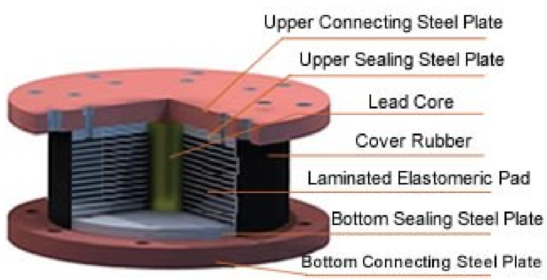

Figure1.1: Lead-Rubber Bearings

Friction-Based Isolators

- Sliding bearings between foundation and structure.
- Types: flat or curved sliders.
- Restoring force provided by springs, rubber layers, or the curved surface shape.

Friction Pendulum Systems (FPS)

- Slider moves on a concave Teflon-coated surface during seismic motion.
- Acts like a pendulum, elongating the structure's period and dissipating energy.
- **Double-Curved FPS:** Combines two concave surfaces, allowing larger displacements while reducing device size.

Figure1.2: Friction Pendulum Systems

Examples of base isolated structures in India and worldwide include the Bhuj Hospital in Gujarat, retrofitted after the 2001 earthquake; the National Centre for Seismic Engineering Research buildings; several bridges in seismic regions like the Chenab Bridge; and critical infrastructure such as hospitals, museums, and government buildings in seismic zones. Globally, iconic base isolated structures include the San Francisco City Hall, Los Angeles Museum of Modern Art, and the Tokyo National Museum, demonstrating the wide application of this technology for earthquake protection.

2. Literature review

Mithun, DileepKumar The study compares seismic responses of RCC, Steel, and Composite G+10 irregular buildings. Analysis is done using ETABS 2015 with fixed base, LRB ,and FPBisolation systems. Base isolation increases flexibility, leading to higher displacements in all models. Story drift significantly reduces in base-isolated models, especially with FPB. Base shear decreases by up to 78% in steel structures with FPB isolators. Time period increases by up to 70% with FPB, reducing seismic demand. Composite structures show moderate displacement and good seismic control. FPB performs slightly better than LRB in reducing drift and base shear. First story driftis higher in isolated models but reduces with height. Overall, FPB is more effective than LRB for irregular medium-rise buildings.

Dr. R. S. Talikoti, Mr.Vinod R. Base isolation reduces earthquake impact on buildings. Study done on a G+15 RCC structure. Analyzed using SAP2000 and El-Centro data. Used Lead Rubber Bearings (LRB) and HDRB. Time period increased: Fixed = 2.65s, LRB = 3.89s.Base shear decreased in isolated structures.Storydisplacement and drift were reduced. Isolators absorb seismic energy, protecting structure. Bracing increased stiffness but less effective than isolation. Conclusion:Base isolation improves seismic performance.

3. Objectives of the study

1) To analyze of RCC G+15 structure by non linear time history method having regular and irregular building with following conditions
- Fixed base
- Base isolator (lead rubber bearing)
- Fixed and partial base isolators.
2) To study the G+15 regular and irregular building in ZoneII and Zone IV seismic condition.
3) To compare the results like joint displacements, story drift, base shear values for rubber base and with fixed support condition.

4. Methodology

In the present study, the seismic performance of a G+15 storey building is evaluated in different seismic zones using II and IV ETABS 2019. Both regular and irregular configurations are considered, and three structural systems are studied: fixed-base, partially base-isolated, and fully base-isolated. Nonlinear time history analysis is carried out using real earthquake ground motion data (El Centro earthquake record) to investigate the effectiveness of base isolation in reducing seismic response.

A total of twelve models are developed and analyzed

A) ZONE II

1. Regular building with fixed support in Zone II
2. Regular building with partial base isolation in Zone II
3. Regular building with full base isolation in Zone II
4. Irregular building with fixed support in Zone II
5. Irregular building with partial base isolation in Zone II
6. Irregular building with full base isolation in Zone II

B) ZONE IV

1. Regular building with fixed support in Zone IV
2. Regular building with partial base isolation in Zone IV
3. Regular building with full base isolation in Zone IV
4. Irregular building with fixed support in Zone IV
5. Irregular building with partial base isolation in Zone IV
6. Irregular building with full base isolation in Zone IV

The base isolator used is lead rubber bearing and its Properties of LRB Isolators are modelled as spring elements (point springs) in ETABS and their properties of the lead rubber bearing isolator are referred from Torunbalci1 and G. Ozpalanlar octo.12-17(2008) [10] pp: 3-4, based on which they are enlisted below in table below

Table 4.1: Properties of lead rubber bearing

Parameter	Value	Unit
U1 Linear Effective Stiffness	15,000,000	kN/m
U2, U3 Linear Effective Stiffness	800	kN/m
U2, U3 Nonlinear Stiffness	250	kN/m
U2, U3 Yield Strength	80	kN
U2, U3 Post-yield Stiffness Ratio	0.10	–

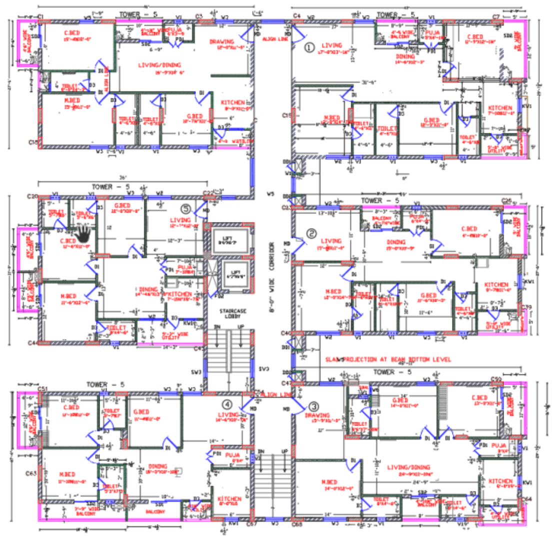

Fig 4.1: Plan of the Building (Regular and irregular structure)

There are 2 types of building regular and irregular building

Regular building : The building considered for the study is a G+15 storey structure with plan dimensions of approximately 31.12m x 32.31 m

Basic parameters considered for the analysis are

1. Utility of Buildings : Residential Building
2. No of Story: 16 Stories (G+15 Building)
3. Grade of concrete : M30
4. Grade of Reinforcing steel : HYSD Fe 550
5. Type of construction: RCC framed structure
6. Dimensions of beam : 300mm X 600mm
7. Dimensions of column: 300mm X1200mm
8. Thickness of slab : 150mm
9. Height of bottom story : 4m
10. Height of Remaining story : 3m
11. Building height : 48 m
12. Live load : 2 KN/m2
13. Floor finish load : 1.5 KN/m2
14. Wall load : 11 KN/m
15. Density of concrete : 25 KN/m3
16. Loads considered in Buildings : Dead load, Live load, Floor load, Earthquake load, Wind load.
17. Seismic Zones : Zone II, Zone IV (Bangalore, Delhi)
18. Site type : II
19. Importance factor : 1.15
20. Response reduction factor : 5
21. Damping Ratio : 5%

22. Structure class : B
23. Basic wind speed : 39m/s
24. Method of Analysis : Time history Analysis
25. Wind design code : IS 875: 1987 (Part 3)
26. RCC design code : IS 456:2000
27. Steel design code : IS 800: 2007
28. Earth quake design code: IS 1893: 2002 (Part 1).

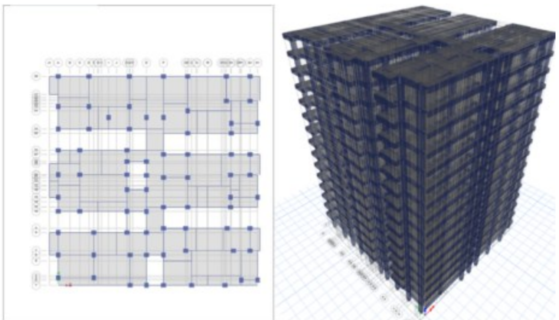

Fig 4.2: Regular building

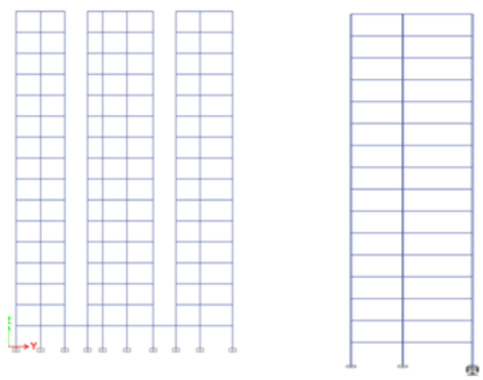

Fig 4.3: Regular building with fixed support and Regular Building with partial base isolation

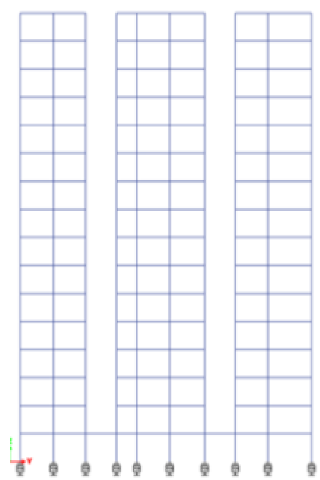

Fig 4.4: Regular Building with full base isolation

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ISSN 2249-3352 (P) 2278-0505 (E)
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Irregular building : The building considered for the study is a G+15 storey structure with plan dimensions of approximately 31.12m x 32.31m. The 1 st 5 storey are area is 31.12m x 32.31m and from 5 th to 10 thstorey area is reduced to 30 percent and from 10 th to 15 thstorey area is reduced to 70 percent.

Basic parameters considered for the analysis are
1. Utility of Buildings : Residential Building
2. No of Story : 16 Stories (G+15 Building)
3. Grade of concrete : M30
4. Grade of Reinforcing steel : HYSD Fe 550
5. Type of construction : RCC framed structure
6. Dimensions of beam : 300mm X 600mm
7. Dimensions of column : 300mm X1200mm
8. Thickness of slab : 150mm
9. Height of bottom story : 4m
10. Height of Remaining story : 3m
11. Building height : 48 m
12. Live load : 2 KN/m2
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15. Density of concrete : 25 KN/m3
16. Loads considered in Buildings : Dead load, Live load, Floor load, Earthquake load and Wind load.
17. Seismic Zones : Zone II, Zone IV (Bangalore, Delhi)
18. Site type : II
19. Importance factor : 1.15
20. Response reduction factor : 5
21. Damping Ratio : 5%
22. Structure class : B
23. Basic wind speed : 39m/s
24. Method of Analysis : Time history Analysis
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26. RCC design code : IS 456:2000
27. Steel design code : IS 800: 2007
28. Earth quake design code: IS 1893: 2002 (Part 1).

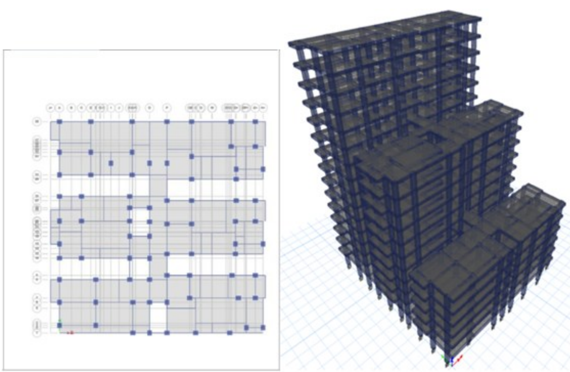

Fig 4.5: Model of irregular building

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UGC Approved Journal

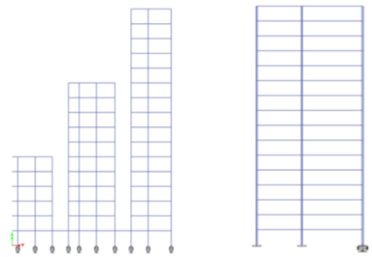

Fig 4.6: Model of irregular building with full base isolator and Model of irregular building with partial base isolator

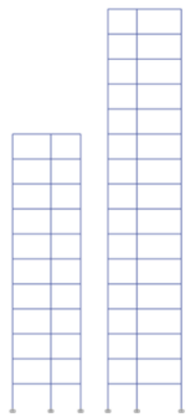

Fig 4.7: Irregular building with fixed support

Seismic Isolation

Seismic isolation is a technique used in earthquake engineering to protect structures by decoupling the superstructure from its foundation. It reduces the transmission of ground motion, thereby minimizing lateral displacements (drift), accelerations, and damage to structural and non-structural components.

The principle is based on modifying the dynamic characteristics of the structure—mainly stiffness, damping, and mass distribution—so that the natural period of the isolated building is shifted away from the predominant earthquake frequencies. This is achieved by placing isolation devices with low horizontal stiffness between the structure and the foundation.

The system works by reducing seismic energy input:

$$E=E_k+E_s+E_h+E_v$$

where E is the total seismic energy, consisting of kinetic (E_{k}_), elastic strain (Es), hysteretic damping (E_h), and viscous damping energy (E_v).

By increasing damping and flexibility, seismic isolation lowers acceleration demands while allowing controlled displacements. Its effectiveness also depends on **soil conditions**: good performance is observed in stiff soils, whereas soft soils may reduce isolation efficiency.

Time History Method

- The time history method is one of the most accurate techniques for analysing the seismic response of structures.
- In this method, a mathematical model of the building is subjected to actual earthquake ground motion records (accelerograms).
- The analysis follows the ground motion *step by step in time*, so both elastic and inelastic behaviour can be captured.

5. Results and analysis

In this study, I analyze the seismic performance of three types of buildings using time history analysis, both with and without base isolation, including a partially base-isolated building. To simulate the effects of an earthquake, real ground motion data is used. By performing time history analysis, I evaluate key seismic response parameters such as displacement, inter-story drift, and base shear.

5.1 Storey displacement

The following table presents the storey displacement values obtained from time history analysis for three building models: a normal building, a partially base-isolated building, and a fully base- isolated building. Real earthquake ground motion data was used to simulate seismic activity.

5.2 Regular Building Results (Zone II Results) Comparison of Displacement Values:

From the below figure 5.1, the comparison shows that the normal building experiences the highest displacement at all storeys, while partial and full base isolation help reduce these values. Partial base isolation lowers displacement by about 15–25% compared to the normal building, whereas full base isolation achieves a much greater reduction of around 40–50%. This trend is consistent across all storeys, from the top floors to the lower levels. Overall, full base isolation proves to be the most effective method in minimizing displacement and enhancing seismic performance.

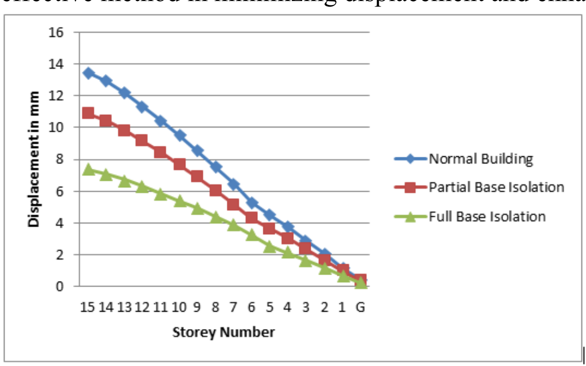

Fig 5.1: Comparison of Displacement Values

5.3 Regular Building Zone IV Results Comparison of Displacement Values

From the below figure 5.2, the displacement values clearly show that the normal building experiences the maximum displacement across all storeys, while both partial and full base isolation help in reducing these values. Partial base isolation provides a moderate reduction of about 15–20% compared to the normal case, whereas full base isolation achieves a much larger reduction of around 40–45%. This decreasing trend in displacement is consistent from the top floors down to the ground level. Overall, full base isolation proves to be the most effective method in minimizing displacement and enhancing the seismic safety of the structure.

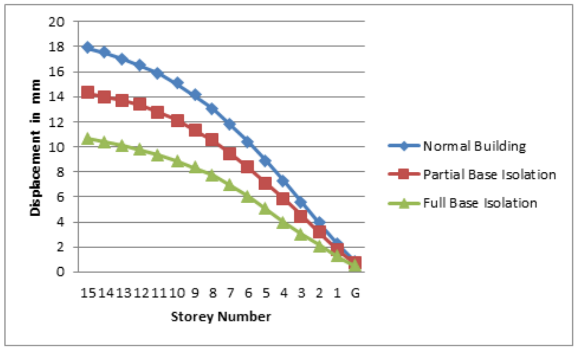

Fig 5.2: Comparison of Displacement Values

5.4 Irregular Building Results Zone II Results Comparison of Displacement Values

From the below figure 5.3, the displacement values indicate that the normal building has the maximum displacements across storeys, while base isolation systems help reduce them. Partial base isolation achieves noticeable reductions at upper storeys but shows uneven performance, with some lower storeys even recording higher values than the normal case. Full base isolation provides consistent improvement, reducing displacement by about 30–40% at critical levels such as the roof and the first storey. At the ground level, displacement drops from 0.373 in the normal case to 0.225 with full isolation, showing nearly 40% reduction. Overall, full base isolation proves to be the most reliable and effective method in minimizing storey displacements and enhancing seismic performance.

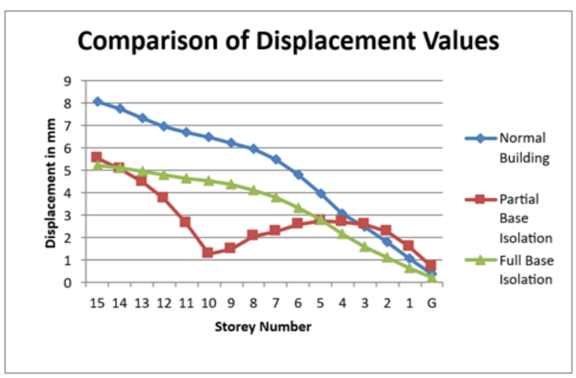

Fig 5.3: Comparison of Displacement Values

5.5 Zone IV Results Comparison of Displacement Values

From the below figure 5.4, the displacement values clearly show that the normal building experiences the maximum displacements at all storeys, while both partial and full base isolation reduce them effectively. Partial base isolation achieves about 15–20% reduction across most storeys, indicating moderate improvement. Full base isolation consistently provides the best performance, reducing displacements by about 30–40% compared to the normal case. The reduction is evident at the roof level, at the critical first storey, and even at the ground floor. Overall, full base isolation proves to be the most effective system in controlling displacements and improving seismic safety.

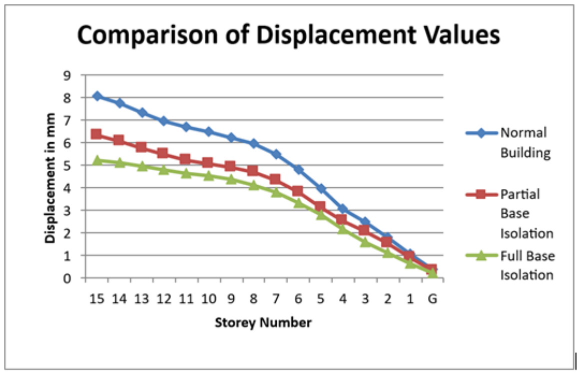

Fig 5.4: Comparison of Displacement Values

5.6 Storey drift

The table below shows the inter-storey drift values obtained from time history analysis for three different building models: normal, partially base-isolated, and fully base-isolated. From the below figure 5.5, the drift values indicate that the normal building records the highest drift at every storey, while partial and full base isolation show reduced values. Partial base isolation achieves a reduction of about 15–20%, whereas full base isolation results in a greater reduction of nearly 35–45%. This decreasing trend is consistent across all floors, confirming the efficiency of isolation systems. Among the two, full base isolation provides the maximum benefit in minimizing drift. Thus, base isolation, especially full isolation, significantly improves the seismic performance of the structure.

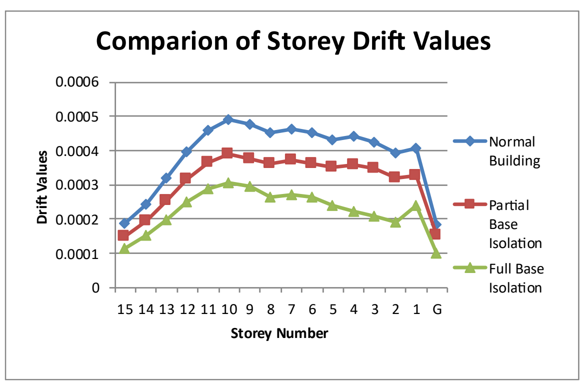

Fig 5.5: Comparison of Storey Drift Values

5.7 Zone IV Results Comparison of Storey drift

From the below figure 5.6, the drift results show that the normal building experiences the maximum values across all storeys, while base isolation significantly reduces them. Partial base isolation achieves a reduction of about 15–20%, whereas full base isolation provides a much greater reduction of nearly 35–45%. The most critical storey drift at the 1st floor decreases from 0.000755 in the normal case to 0.000418 in the fully isolated case. This consistent reduction pattern is observed from the ground up to the top storey. Overall, full base isolation is the most effective technique in controlling storey drift and improving the seismic safety of the structure.

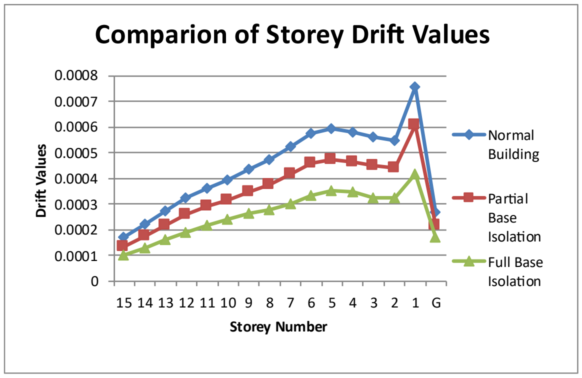

Fig 5.6: Comparison of Storey Drift Values

5.8 Irregular building (Zone II) Comparison of Storey drift

From the figure 5.7, the drift results show that the normal building consistently records the highest values, while base isolation systems help reduce them effectively. Partial base isolation lowers drift by about 15–20%, whereas full base isolation achieves much higher reductions of about 35–45%. The maximum drift at the critical storey reduces from 0.002446 in the normal case to 0.001393 in the fully isolated case. Even at the ground level, drift is reduced by nearly 46% with full isolation. Overall, full base isolation provides the best performance in controlling storey drift and ensuring seismic safety of the structure.

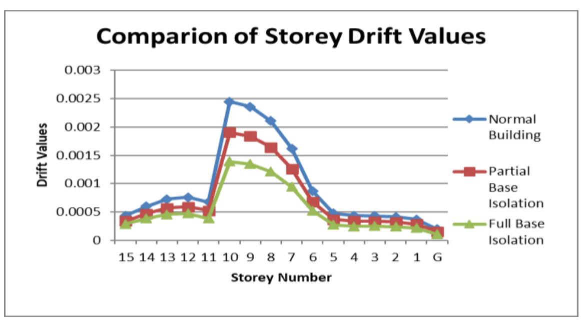

Fig 5.7: Comparison of Storey Drift Value

5.9 Irregular building (Zone IV) Comparison of Storey drift

From the below table figure 5.8, the data clearly shows that storey drift decreases progressively from Normal Building to Partial Base Isolation and further to Full Base Isolation at every storey level. The maximum drift occurs at storey 10, with values of 0.00245 for the normal building, 0.0018 with partial isolation, and 0.00139 with full isolation. This reflects a reduction of about 27% in drift when using partial base isolation and nearly 43% reduction with full base isolation compared to the normal building at the critical storey. Drift values decrease steadily from mid-height towards both the ground and top storeys, which is typical for multi-storey buildings during seismic events. The base isolation techniques are effective in controlling seismic drift, enhancing structural performance and occupant safety.

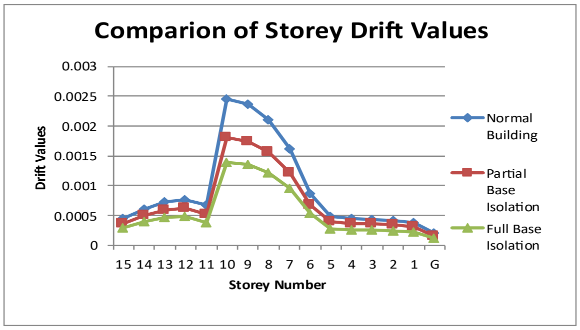

Fig 5.8: Comparison of Storey Drift Values

5.10 Base shear

The table below presents the base shear values obtained from time history analysis for three structural configurations: a normal building, a partially base-isolated building, and a fully base-isolated building. Base shear represents the total horizontal force at the base of the structure due to seismic loading. It is a critical factor in understanding how much earthquake force a structure must resist.

From the below figure 5.9, the base shear is highest in the normal building, indicating greater seismic demand. With partial base isolation, the base shear decreases by about 20%, showing a moderate improvement. Full base isolation provides the maximum benefit, reducing base shear by nearly 39% compared to the normal building. Even when compared with partial isolation, full isolation achieves an additional 23% reduction. Thus, full base isolation proves to be the most effective solution in minimizing base shear and enhancing seismic performance.

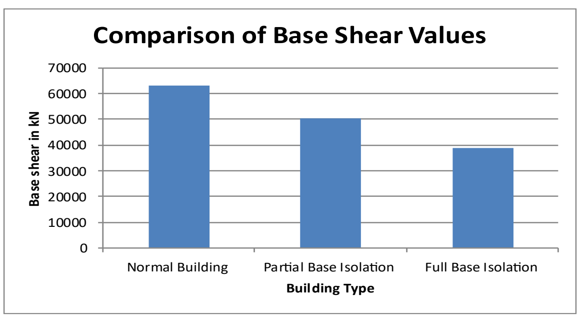

Fig 5.9: Comparison of Base Shear Values

5.11 Regular Building Results (Zone 4) Comparison of base shear

From the below figure 5.10, the base shear is maximum in the normal building, reflecting higher seismic demand. With partial base isolation, the base shear decreases by about 20%, showing moderate effectiveness. Full base isolation achieves a much greater reduction of nearly 40% compared to the normal case. Even when compared to partial isolation, full isolation further reduces the base shear by about 25%. Hence, full base isolation is the most effective strategy to minimize base shear and improve the seismic safety of the structure.

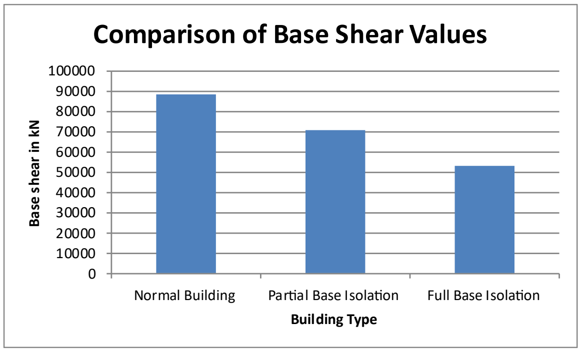

Fig 5.10: Comparison of Base Shear Values

5.12 Irregular Building Results(Zone II) Comparison of base shear

From the below figure 5.11, the base shear values decrease significantly when using base isolation compared to a normal building. Specifically, partial base isolation reduces the base shear from 41,420 kN to 29,480 kN (~29% reduction). Full base isolation further reduces the base shear to 27,214 kN (~34% reduction compared to normal). This reduction indicates that base isolation systems effectively reduce seismic forces transmitted to the structure in Zone 2. Lower base shear means less demand on structural elements and foundations, improving safety and potentially reducing construction costs

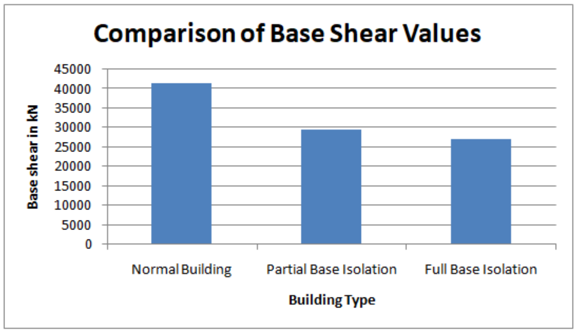

Fig 5.11: Comparison of Base Shear Values

5.13 Irregular Building Results (Zone 4) Comparison of base shear

From the below figure 5.12, the base shear in a normal building is highest at 44,428 kN, reflecting the greater seismic hazard in Zone 4. Partial base isolation reduces the base shear to 36,353 kN, which is about an 18% reduction compared to the normal building. Full base isolation further lowers the base shear to 27,214 kN, achieving a significant 36% reduction compared to the normal building. This shows that base isolation is highly effective in mitigating seismic forces even in high-risk zones like Zone 4. Reduced base shear means less stress on the structure and foundations, increasing safety and potentially lowering repair costs after earthquakes

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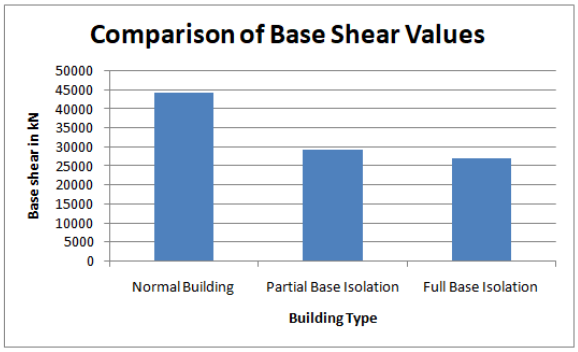

Fig 5.12: of Base Shear Values

6. Observations

1) By Comparing regular building and irregular building for zone 2

- Displacement: Regular buildings show top displacement of ~13.4 mm (Normal), reduced to ~10.8 mm (Partial) and ~7.4 mm (Full). Irregular buildings show smaller absolute values but reduction efficiency of partial isolation is poor, while full isolation reduces ~30–35%.
- Drift: Regular buildings have small drifts (max ~0.00049) which reduce to ~0.00031 with full isolation. Irregular buildings experience much larger drifts (up to ~0.00245), indicating greater vulnerability, but full isolation reduces by ~40–45%.
- Base Shear: For the regular building, base shear is reduced by about 21% with partial isolation and 38.8% with full isolation.
- For the irregular building, the reduction is about 18.8% with partial isolation and 34.3% with full isolation.

2) By Comparing regular building and irregular building for zone 4

- Displacement: Regular buildings show higher top displacement ~17.9 mm (Normal), reduced to ~14.3 mm (Partial) and ~10.7 mm (Full). Irregular buildings show displacement, but reductions are consistent (~35–40% in full isolation).
- Drift: Regular buildings have higher drifts (max ~0.00059), reduced to ~0.00035 with full isolation. Irregular buildings again show very high drifts (~0.00245), but full isolation reduces them effectively.
- Base Shear: For the regular building, the base shear is reduced by about 20% with partial isolation and 40% with full isolation. For the irregular building, the reduction is about 18% with partial isolation and 38.7% with full isolation.

7. Conclusion

The comparative study of 12 models across Zones II and IV reveals that Full Base Isolation consistently outperforms both Normal and Partial Base-Isolated structures in controlling seismic displacement, drift, and base shear. While Partial Base Isolation offers adequate safety for regular structures in moderate seismic zones (Zone II), it is essential for all buildings in high seismic zones (Zone IV) and for irregular structures in any seismic zone. Base isolation not only enhances structural safety and serviceability but also ensures quicker post-earthquake recovery and reduced repair costs.

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