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Comparative Seismic Performance Assessment of Fixed-base and base-Isolated Multi-Storey Structures

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***Abstract*— Seismic design of multi-story buildings aims to ensure safety, serviceability, and stable structural performance during earthquake events. Conventional fixed-base buildings are designed to resist seismic forces through strength and ductility. However, during strong ground motion, such structures often experience high base shear and excessive inter-story drift, which causes significant damage to the structures. To overcome these limitations, base isolation has emerged as an effective seismic protection technique that reduces the earthquake forces to the superstructure of a building and decreases the overall seismic demand. In this study, a comparative seismic evaluation of base-isolated reinforced concrete multi-story buildings and fixed-base buildings was performed using advanced analytical techniques. Two building models were considered for the seismic analysis using the STAAD Pro software. Model one is a conventional fixed-base system, and model two is a base-isolated system. Lead rubber bearings are introduced at the base of the isolated model and idealized using equivalent linear spring damper elements. According to IS1893:2016(Part-1) for seismic Zone V, both model's seismic responses are assessed using response spectrum analysis. Key response factors, such as base shear act at foundation level, inter story, and roof displacement were analyzed and compared. The results give that the base-isolated structure shows a rise in the fundamental time period, which leads to a considerably lower the seismic forces acting on the superstructure. Compared to the fixed-base building, the base-isolated model exhibits less base shear and reduces the inter-story drift. However, the roof displacement remained within the permissible limits. The study concluded that the base isolation system is a more effective and reliable method than the fixed base to improve the seismic resistance and resilience of multistory buildings in high-seismic regions.**

***Index Terms*— Base isolation, Response spectrum analysis, Fixed-base structure, STAAD Pro, Seismic performance, Lead rubber bearing.**

I. INTRODUCTION

A. The Challenge of Seismic Risk in Multi-Storied Buildings

Seismic activity continues to represent a major risk for building environments in densely populated urban areas where multistory buildings are widely spread. Traditional earthquake-resistant design is generally based on the principle that structures should not be damaged during minor earthquakes, experience repairable damage under moderate shaking, and avoid collapse during severe seismic events.

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To achieve these objectives, buildings are designed with higher strength and stiffness so that earthquake forces are resisted by the controlled yielding at structural primary members such as columns and beams.
This design philosophy is effective in preventing collapse and protecting human life; however, it often leads to significant damage to nonstructural components, increased repair costs, and a long period of disputation over building functionality after an earthquake. In conventional fixed-base structures seismic forces are directly transferred to the structure, causing higher demand on structural elements and increasing the overall vulnerability during strong ground motions. This approach may not be suitable for essential services such as hospitals, critical infrastructure, and emergency response centers, which must remain operational during earthquakes. Further, a substantial portion of the noncompliance with current seismic codes emphasizes the need for more effective and advanced seismic protection techniques.

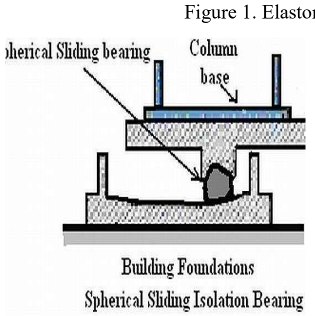
B. Advancements in Seismic Protection Strategies

To overcome drawbacks of conventional seismic design methods and to improve overall performance of structures during earthquake various advanced control technologies have been developed over a time period. Active, passive, semi active and hybrid control systems are the categories into which these technologies fall. Because of their affordability, dependability, and ease of use, passive control systems are the most popular of these base isolation and supplemental damping systems. Two popular passive control strategies that significantly lessen a structure's seismic response are base isolation and supplemental damping.[1]

C. Base Isolation Systems

A sophisticated method of seismic protection, base isolation involves separating the building's superstructure from its foundation. By adding a flexible layer at the base, this technique aims to change how a building reacts to ground movements during an earthquake. Because of this flexibility the building's natural time period is extended, and its response is shifted away from the earthquake's leading frequencies, which lowers seismic forces. Because of this separation, the building moves much less, and the majority of the movement caused by earthquakes beneath it is accommodated by the ground and the isolation system. Elastomeric bearings and building-type systems are common base isolation devices. Lead rubber bearings and high damping rubber bearings are examples of elastomeric bearings, whereas friction pendulum systems and flat sliding bearings are examples of sliding systems. Lead rubber bearings have a lead core to disperse seismic energy, and the rubber layers around it provide flexibility and the ability to realign after an earthquake. The increased flexibility of the system can lead to significant displacements at the isolation level, even though base isolation is very effective in limiting structural damage and reducing floor accelerations. Adequate clearance or separation gaps around the building must be provided in order to accommodate these displacements. Stability issues are raised due to excessive isolation, especially in tall or slender buildings and also in structures that rest on soft soil conditions.

Figure 1. Elastomeric bearings



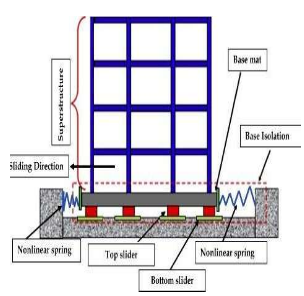


Figure 2. Sliding bearing   Figure 3. Base Isolation

II. Literature Review

A number of researchers have stressed the significance of seismic analysis of buildings in India because of the country's varied geological and tectonic conditions. A study shows that the division of India into seismic Zone II, III, IV, and V helps engineers to design the structures as per regional earthquake intensity. Researchers have explained it to assess the structural performance and safety under seismic forces and keep it from failing. Because STAAD Pro is accurate and compliant with Indian Standard codes, many studies have used it to analyze multistory RCC buildings. Higher seismic zones are associated with increased seismic forces, story displacement, and member forces, according to prior research on G+5 and comparable multistory buildings. Many authors compare different cities that represent different seismic zones and buildings in higher zones that require stronger design measures. Appropriate consideration of load combinations and seismic parameters is crucial for guaranteeing structural safety and serviceability. The majority of studies only use linear analysis, which suggests that more research using sophisticated seismic performance evaluation methods is required. [2] RCC multi-story buildings are extremely susceptible to seismic forces in earthquake-prone areas. Conventional fixed-base buildings suffer greater base shear and story displacement during earthquakes. Base isolation is a useful method for lowering seismic forces that are transmitted to buildings. Base isolation increases natural period and decreases seismic structural acceleration, according to research. Base isolation systems that are commonly utilized include natural rubber and lead rubber bearings. Base-isolated structures outperform fixed-base structures under seismic loading, according to earlier research. [3] The majority of India's hilly terrain is seismically active. IS: 1893-2002 states that practically all multi-story buildings need to be examined for three systems in dimensions. Floor plans for buildings are perceived as asymmetrical. Response spectrum analysis is used in the study to compare various dampers, and the G+15 building's bending, shear, drift, time period, torsion, and frequency values are compared. [4] A variety of isolators, including friction pendulum systems, lead rubber bearings, and high-damping rubber bearings, are examined and their potential to influence the fundamental time period of structures is emphasized. Improved seismic performance and decreased inter-story drift in isolated buildings are confirmed by analytical and numerical studies. Use springs, dampers, or nonlinear elements to accurately model isolation for realistic response prediction.[5] The increasing risk of earthquakes has led to extensive research on the seismic performance of residential RCC buildings. According to research, conventional fixed-base structures sustain substantial damage when subjected to seismic loading. Numerous response control strategies have been put forth to increase seismic resistance. Base isolation has been found to be an efficient way to lessen seismic forces among these. Studies show that base isolation increases the natural time period of buildings and reduces acceleration. In practice, lead rubber bearings and high-damping rubber bearings are frequently utilized isolators. Research demonstrates that base-isolated structures perform better seismically and are safer than fixed-base structures.[6,7] A seismic performance of G+10 multi-storied steel building along with and excluding dampers such as base isolation system, friction damper and viscous damper is evaluate for seismic zone II, zone III, zone IV, zone V by using ETABs software.[8] The analysis is conducted on active, passive, and semi-active isolation systems with their key components, considering dampers, bearings and actuators.[9] An analysis of the seismic performance of a 26-story base-isolated shear wall structure built on a deep alluvial deposit close to a fault. The combined impact of deep site conditions and seismic isolation on structural responses is assessed using computational model that takes soil-foundation interaction into account. [10]

III. Methodology and Model Description

The present study adopts a numerical and analytical approach for comparing seismic performance of fixed-base and base-isolated multi-story reinforced concrete buildings in seismic zone V. STAAD Pro structural analysis and design software is used for structural modeling and analysis.
Two model are developed using STAAD Pro
Model I: Fixed-base building with conventional rigid supports at the foundation level.
Model II: Base isolated building where fixed supports are replaced by isolator.[11]
Seismic analysis is carried out using Response Spectrum Analysis. Load combinations are applied according to IS 456 and IS 875.
Data considered for analysis is as follows.

- Typical story height - 3m
- Ground story height -3m
- Building Width -14m
- Total building height-39m

- Building length -15m
- Total building height-39m
- Number of story-13 (G+12)
- Thickness of slab-150mm
- Support-Fixed (model 1),
- Base isolated (model 2)
- Size of column- 0.45mX0.75m
- Size of beam -0.3mX0.6m
- Grade used for concrete is-M30
- Grade used for steel is-Fe500
- Live load-3KN/M2
- Dead load-3KN/M2
- Density of concrete-25KN/M3
- Seismic Zone-V
- Site type- type 2
- Response reduction factor-5
- Importance factor-1
- Damping Ratio- 5%
- Soil type- medium soil (Medium dense sand)
- IS456:2000
- IS 875 for design loads
- IS 1893: 2016 (part 1)- Earthquake design code
- Stiffness values - KFX -Horizontal stiffness of isolator (X direction) = 1500kn/m, KFY - (Vertical stiffness of isolator (Y direction) = 10000000 kn/m, KFZ -Horizontal stiffness of isolator (z direction) =1500kn/m

Model 1: Fixed base building with conventional supports at the foundation level. Figure 4

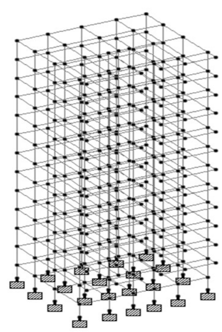


Figure 4. Model-1

Model II: Base isolated building where fixed rigid supports are replaced by isolator. Figure 5

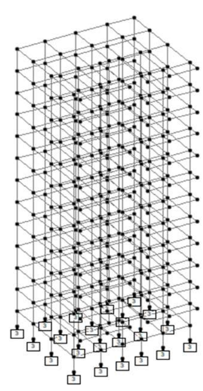
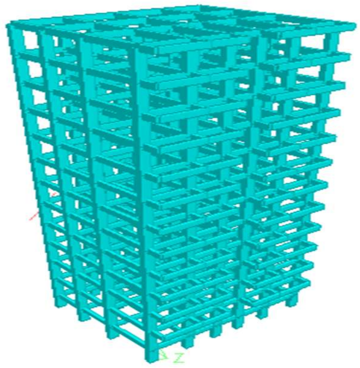


Figure 5. Model-2



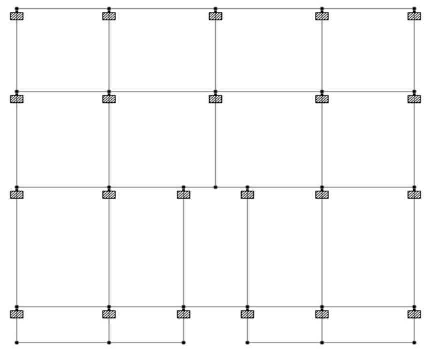


Figure 6. 3D Model Figure 7. Line plan of Model-1 and model-2

IV. Results and Discussion

For two structural configurations, the seismic performance of a 13-story RCC building model in seismic zone V was assessed. Model I: Fixed base building with conventional rigid supports at the foundation level. Model II: An isolated base building with an isolator in place of fixed supports. The comparison is based on base story drift, base shear, and lateral displacement under seismic loading, which are crucial response parameters in severe seismic regions. The analysis is conducted in compliance with IS1893 (Part 1).

Base Shear-For the zone V fixed-base building model depicted in Figure 8. Base shear in the base-isolated building model is 839 KN, while base shear in the design is 1455 KN. The findings indicate that base-isolated buildings require less seismic force. Because of the strong ground motion in seismic zone V, fixed-base structures are subject to significant inertia forces because of their comparatively short natural periods. By moving the structural response to a lower spectral acceleration region, base isolation lengthens the fundamental time period of the structure. Consequently, the base-isolated structure has a base shear reduction of approximately 42% when compared to the fixed base system. Lower axial forces, bending moments, and shear forces in structural members result from a decrease in base shear, especially in zone V. This enhances safety and lowers the possibility of structural damage.

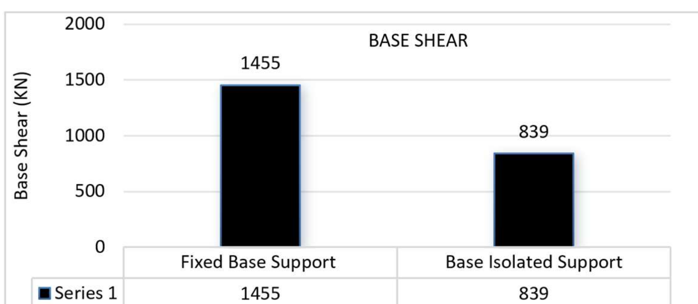


Figure 8. Comparison of Base Shear for Type of Structure Model

Story Drift-As seen in Figures 9 and 10, the base-isolated structure had a decrease in story drift to 0.12 cm in the X direction and 0.14 cm in the Z direction, while the fixed base structure displayed a comparatively higher inter-story drift value of 0.55 cm in the X direction and 0.16 cm in the Z direction, with maximum drift occurring at the middle story. In the X direction, drift has decreased by 88%, while in the Z direction, it has decreased by 25%. The story drift limit, according to IS 1893:2016 (Part 1), is 0.004h = 0.004X3000 = 12 mm.Every story drift value was close to the codal drift limit and stayed well within allowable bounds. Higher inter-story drift and a greater potential for damage result from the fixed base system's primary absorption of seismic energy through the deformation of beams and columns. Relative displacement between successive floors is limited in base isolation because the majority of lateral deformation occurs at the isolation level. Both structural and non-structural components are less damaged as a result of this behavior. Story drift reduction improves serviceability, which guarantees improved performance under intense seismic excitation, such as in zone V.

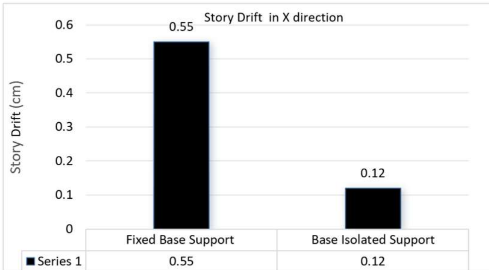


Figure 9. Comparison of Story Drift in X direction for Type of Structure Model

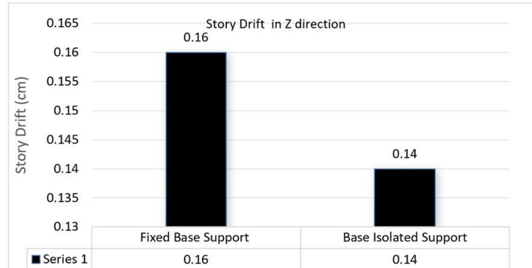


Figure 10. Comparison of Story Drift in Z direction for Type of Structure Model

A. Lateral Displacement

The roof displacement of the fixed base structure is 5.04cm which is comparatively lower than base-isolated structure that is 15.16cm as shown in figure 11 and figure 12. IS 1893 (Part1) does not give direct value for lateral displacement, as seismic performance is controlled by inter story drift limit which is 0.004 times storey height, In this study codal drift requirements are satisfied thus ensure the displacement criteria. The base-isolated model showed higher overall lateral displacement, with a major portion of displacement concentrated at the base isolation level, while the superstructure experienced relatively small deformations. Although the total displacement of the base-isolated structure is higher, this behavior is desirable and intentional. The isolation system allows controlled movement at the base, which dissipates seismic energy and protects the superstructure from excessive deformation. In the fixed base structure, displacement is distributed along the height, resulting in higher deformation demands on beams and columns, which may lead to cracking or yielding during severe earthquakes. Thus, in zone V conditions, increased base displacement coupled with reduced superstructure displacement confirms the effectiveness of the base isolation as a seismic protection technique. Despite the base isolated structure's greater overall displacement, this behavior is desired and deliberate. By enabling controlled movement at the base, the isolation system disperses seismic energy and shields the superstructure from undue deformation. Because displacement is dispersed throughout the height of the fixed base infrastructure, beams and columns are subjected to grater deformation demands, which may cause them to crack or yield during strong earthquakes. Therefore, increased base displacement combined with decreased superstructure displacement under Zone V. Conditions validate base isolation's efficiency as a seismic protection method.

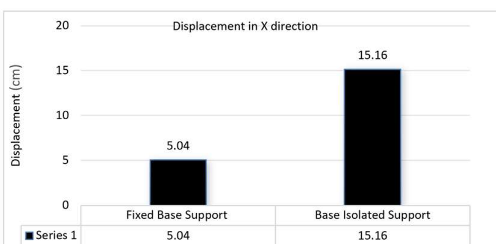


Figure 11. Comparison of Displacement in X direction for Type of structure model

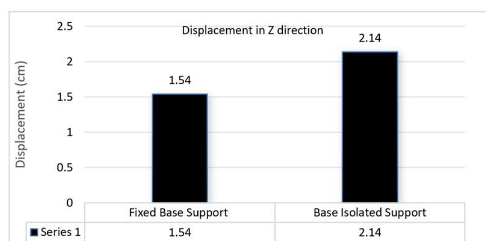


Figure 12. Comparison of Displacement in Z direction for Type of structure model

TABLE I: FIXED BASE AND ISOLATION STRUCTURE

Sr. No.	Parameter	Fixed Base Structure	Base Isolation Structure
1	Base Shear (KN)	1455	839
2	Storey Drift (cm)	X direction 0.55 Z direction 0.16	X direction 0.12 Z direction 0.14
3	Displacement (cm)	X direction 5.04 Z direction 1.54	X direction 15.16 Z direction 2.14

All things considered, Table1's results make it abundantly evident that base isolation greatly enhances seismic performance when compared to traditional fixed base system. Fixed base structure relies on strength and ductility to resist seismic forces, whereas base isolated structures reduce the seismic demand by modifying dynamic characteristics.

V. SUMMARY

Two building models created with STAAD Pro were compared analytically in this study Model 1 is a fixed base building with traditional rigid foundation level supports, Model II is a base isolated building with isolation in place of fixed supports. For seismic zone V. both models were examined using STAAD under the same gravity and seismic loading conditions. Pro in a compliance with IS 1893:2016 (Part 1) and IS 456:2000 regulations. To comprehend overall structural behavior, three structural response parameters-base shear, story drift, and lateral displacement were assessed. The findings show that in comparison to a traditional fixed base system, base isolation enhances seismic performance.

VI. CONCLUSION

Based on analytical results obtained in this study, conclusions are as follows

- The study investigated a 13-story RCC building in seismic zone V by comparing fixed base support and base isolation systems under earthquake loading as per IS 1893-2016 (Part 1). Story drift, base shear and lateral displacement were compared. These are important factors that are control serviceability and structural safety.
- The analysis's findings indicate a fixed base structure with high base shear which raises the force required on foundations, beams and columns, In contrast, base shear in a isolated structure is about 42% lower than in a fixed base structure because of the decoupling of the superstructure from the ground and as increases in the fundamental time period.
- The findings show that the story drift is grater in a fixed-base structures than in base isolated structures. Story drift is lowered to 77% in base isolated structures, which aids in shielding the superstructure from powerful earthquakes.
- The outcome demonstrates that the base isolated structure's total lateral displacement was greater than the fixed base structure. While the upper story saw comparatively little structural member deformation, the displacement was greater at the isolation level.
- Base isolation greatly improves the seismic behavior of multi-story RCC buildings in Seismic zone V. according to a comparative analysis.

REFERENCES

[1] Prasanna Madanant Phadnis, Prof.S.T.Pawar , "A study of effect of various damping systems on RCC structures subjected to specified ground motion", IJSART - Volume 3, PP 1047-1053, Issue 6 –JUNE 2017.

[2] B. Ramakrishna, G Swetha, SK Amreen Shazia, K Sai Kiran and S Durga Venkata Dinesh, "Analysis of multi storied building in different seismic zones using STAAD Pro", ISTCE, IOP Conf. Series: Earth and Environmental Science, 2021

[3] Md Qurban Ali, Koyel Mandal, Diksha Navle, Tuba Shaikh, Professor Shweta Motharkar, "Comparative study of different types of Base Isolators in multistoried building", IJIRT, Volume 11, Issue 3, ISSN: 2349-6002, pp 1144-1152, August 2024.

[4] Bbasipaka Bharathi, V. Akhil Siddhartha, "Comparative study of various types of dampers used for G+15 Multi Story R.C.C. building", Vol 13, ISSN:0377-9254, pp 908-914, Issue 8, 2022.

[5] Dr. Thamir Al-Azawi, Dr. AbdulMuttalib I.S. AlMusaui, Dr. Salah R. Al-Zaidee, "Modeling of Base Isolator as structural element", pp 92-103, July 2017.

[6] Asma Belbachir, Abdelkader Benanane, Abderrahmane Ouazir, Zouaoui R. Harrat, Marijana Hadzima-Nyarko, Dorin Radu, Ercan I¸ sık, Zouhir S. M. Louhibi and Sofiane Amziane, "Enhancing the seismic response of residential RC buildings with an Innovative Base Isolation Technique", 2023.

[7] Nithin A V, Asha Varma P, "Seismic Base Isolators under individual and combined use in multi storied buildings A Review", IRJET Volume: 04, pp 1232-1236, Issue: 02, Feb -2017.

[8] Aishwarya Y. Patil Yogesh Patil, R. D. Patil Patil, "Seismic analysis of a multi storied steel building with different types of damper and base isolation", March 2024.

[9] Tariq H.R. Bermany, S. A. Osman, Mohd Yazmil Md. Yatim," A state-of-the-art analysis of base isolation systems and future directions for developing a novel multi-directional smart-hybrid isolation system integrated with earthquake early warning system for building structures", 2025.

[10] Siyu Tao, Zhe Qu, Yuli Huang, "Seismic performance of a high-rise Base-isolated RC shear wall building on Deep Deposit", September 2025.

[11] Akshay Chincholea, Charanjeet Singh Tumrate Dhaneshwar Mishra b c, "Design of Base Isolation System for a six storey reinforced concrete building", IOP Conf. Series: Earth and Environmental Science, November2022.