

ANALYSIS AND DESIGN OF EARTHQUAKE RESISTANT BUILDING USING BASE ISOLATION

¹Roopa Balakrishnan, ²Aalvi C, ³Sana Fathima K, ⁴Shahana K K

¹Assistant professor, ^{2,3,4}UG Final year student

^{1,2,3,4}Department of Civil Engineering,

^{1,2,3,4}St Thomas College of Engineering and Technology, Kannur, India

Abstract: Earthquakes pose a major threat to the structural integrity and safety of buildings, especially in seismic-prone regions. Conventional structures are designed to resist lateral forces through strength and ductility, but they often sustain significant damage during strong ground motions. To overcome this limitation, the base isolation technique has emerged as an effective method to enhance seismic performance. This study focuses on the analysis and design of an earthquake-resistant building using base isolation, where isolators are introduced between the foundation and the superstructure to decouple the building from ground vibrations. The use of lead-rubber bearings (LRB) and high-damping rubber bearings (HDRB) is explored to reduce acceleration, inter-storey drift, and structural damage. Comparative analysis between a fixed-base and an isolated-base structure is performed using dynamic analysis methods. Results indicate that base isolation significantly improves the building performance by reducing seismic forces and enhancing occupant safety. This technique provides a cost-effective and reliable solution for protecting structures and their contents during earthquakes.

Keywords - Base isolation, Earthquake resistant design, lead rubber bearing, seismic analysis, Structural dynamics, vibration control.

1. INTRODUCTION

Earthquakes are among the most unpredictable and destructive natural disasters, capable of causing severe structural damage and loss of life. The behaviour of a building during an earthquake largely depends on its ability to resist and absorb seismic forces. Traditional fixed-base structures are directly connected to the ground, which causes the entire building to experience ground vibrations, often resulting in high stresses and potential failure of structural components. To address this challenge, engineers have developed innovative earthquake-resistant techniques, among which base isolation has proved to be one of the most effective. The base isolation technique involves installing flexible bearings or isolators such as lead rubber bearings, high-damping rubber bearings, or friction pendulum systems between the building's foundation and its superstructure. These isolators act as energy absorbers, reducing the transmission of ground motion to the upper structure. By decoupling the building from the shaking ground, base isolation minimises inter-storey drift, floor acceleration, and structural deformation, thereby protecting both the structure and its occupants. In this study, the design and analysis of an earthquake-resistant building using the base isolation technique are performed using ETABS software. ETABS provides advanced modelling tools and dynamic analysis capabilities that simulate real seismic conditions and evaluate structural response. The analysis compares the behaviour of a fixed-base building and a base-isolated building under similar earthquake loading conditions. Parameters such as base shear, displacement, natural period, and storey drift are analysed to assess the effectiveness of base isolation. The primary objective of this project is to demonstrate how base isolation significantly enhances seismic performance, ensuring structural safety, stability, and serviceability during earthquake events. The results from ETABS analysis highlight that the implementation of base isolation systems can substantially reduce seismic forces on buildings, making them more resilient and reliable against future earthquakes.

1.1 Base isolation

Base isolation of structures is one of the most desired means to protect it against earthquake forces. It is the fundamental concepts for earthquake engineering which can be defined as separating or decoupling the structure from its foundation. This effects in reduction of inter storey drift and effective displacement in the floors of base isolated structural system, that ensures the least damage to facilities and also provides safety to life and property. The concept of base isolation had been suggested in last few decades, the technologies are made available, the knowledge of base isolation system are getting used, developed and hence established.

Seismic isolation systems are more effective when applied to high stiffness, low-rise buildings, owing to their abilities to alter the characteristic of the building from rigid to flexible. And the gradual increase in number of structures to be isolated enhances the fact that base isolation system is gradually becoming accepted as a proven technology in earthquake hazard mitigation. Interestingly, base isolation is a passive control system; it does not require any external force or energy for its activation. Generally, two basic types of isolation systems. In the first approach the isolation system introduces a layer of low lateral stiffness between the structure and the foundation. With this isolation layer the structure has natural period that is much longer than its fixed base natural period. This lengthening of period can reduce the pseudo-acceleration and hence the earthquake-induced forces in structure. This system is being adopted most widely. The second basic type of isolation system is typified by the sliding system. This works by limiting the transfer of shear across the isolation interface.

1.2 Need Of Base isolation

Base isolation is an important earthquake-resistant technique used to protect buildings from the damaging effects of seismic vibrations. During an earthquake, the ground moves rapidly, transmitting horizontal forces to the building through its foundation.

Conventional buildings are directly connected to the ground, causing large structural forces, vibrations, and deformations. Base isolation reduces this interaction by placing flexible isolators between the building superstructure and its foundation. The main need for base isolation is to reduce the transmission of earthquake energy to the building. Isolators, such as Lead Rubber Bearings (LRB), Friction Pendulum Systems (FPS), and elastomeric bearings, increase the natural time period of the structure and reduce the seismic forces acting on it. As a result, base shear, storey drift, structural deformation, and damage to structural members are significantly reduced. Base isolation also helps protect non-structural components, equipment, furniture, and important contents inside the building. This is particularly important for hospitals, emergency service buildings, museums, data centres, and other critical structures that must remain functional after an earthquake. Therefore, base isolation provides improved seismic performance, enhances occupant safety, reduces repair costs, and increases the overall resilience and serviceability of buildings in earthquake-prone regions.

2. METHODOLOGY

The analysis and design procedure in ETABS begins with the initialization of the standard codes and country codes. The next step involves the creation of grid points and generation of the structural model. When ETABS is opened, a new model is created by entering the required grid dimensions and storey dimensions of the building. After creating the model, the material properties are defined through the Define menu by selecting Material Properties. Materials required for the structural components, such as beams, columns, and slabs, are added with their respective properties and specifications. Subsequently, the required section sizes are defined by selecting Frame Sections and adding the appropriate sections for beams, columns, and other structural members. Once the material and section properties have been defined, the structural components are drawn using the appropriate drawing commands, and the corresponding properties are assigned to the beams and columns. Supports are then assigned at the base of the structure by selecting the required joints and applying the appropriate joint or frame restraints through the Assign menu. The various loads acting on the structure are subsequently defined and assigned. Dead loads are defined using the Static Load Cases option in the Define menu. The dead load includes the self-weight of the structural members and the loads due to external and internal walls. Live loads are assigned separately to the floor and roof levels of the structure. Wind loads are defined and assigned in accordance with IS 875 (Part 3): 1987 by specifying the required wind speed and wind direction. Seismic loads are defined according to IS 1893 by specifying the seismic zone, soil type, response reduction factor, and other relevant parameters in both the X and Y directions. Load combinations are then defined using the Load Combinations option, based on the applicable design code. Finally, after completing all the modelling, property assignment, loading, and load combination procedures, the structural analysis is performed. The model is checked for errors, and the analysis results are evaluated using comparison graphs and other relevant output results.

3. LITERATURE REVIEW

3.1 Poonam mhatre, Saylimhatre, Ashwini p, Steffi, Earthquake resistant structure using base isolation technique.(2021): The journal focus on enhancing the seismic resilience of structures by investigating various base isolation techniques. They aim to assess the effectiveness of different isolation systems in reducing seismic forces and improving structural performance during earthquakes. Through their analysis, they identify key parameters such as displacement, acceleration, and base shear to evaluate the performance of each isolation method. The results indicate that certain base isolation systems significantly reduce seismic responses, leading to improved safety and reduced damage in structures. The study concludes that implementing appropriate base isolation techniques can be a cost-effective and efficient strategy for enhancing the earthquake resistance of buildings.

3.2 Pranay Sirsat, Bharati Changhode, Earthquake resistant analysis and design of G+2 bungalow by using software sap 2000. (2020): This journal focuses on the earthquake-resistant analysis and design of a G+2 residential bungalow using SAP2000 software through the Response Spectrum Analysis method. The study aimed to assess the structure's performance under seismic conditions by analysing load combinations and base shear as per IS 1893 standards.

3.3 Sajid G Saudagar, Ashika P Sapkal, Vikas N Nimbalkar, Analysis of earthquake resistant structures using base isolation (2020): The journal "Analysis of Earthquake Resistant Structures Using Base Isolation" focuses on evaluating the effectiveness of base isolation systems in reducing the seismic impact on multi-storey buildings. Using ETABS software, the study analyses a twelve-storey reinforced concrete structure with and without lead rubber bearings (LRB) through Time History and Response Spectrum methods. The research compares parameters such as displacement, drift, and acceleration under seismic conditions. The findings show that base-isolated structures exhibit higher mode periods and greater flexibility, which significantly reduce the seismic forces transmitted to the superstructure, enhancing overall earthquake resistance and structural safety.

3.4 Ehtisham Uddin Syed, Khaja Musab Manzoor, Analysis and design of buildings using Revit and ETABS software (2022): This journal article presents a detailed study on the structural analysis of a high-rise building under seismic loading conditions. The research utilizes ETABS software for modeling and simulation, focusing on parameters such as Storey displacement, storey drift, and base shear. Different structural configurations are compared to evaluate their performance and stability against earthquake forces. Using software's reduces the manpower and saves time in design, analysis of structures with greater accuracy.

3.5 Prof. Sayali Dharane, Shila Kamble, Vinayak Patil, Rahul Phad, Akanksha Mohite, Review on design of building with base isolation techniques (2024): The journal "Review on Design of Building with Base Isolation Techniques" focuses on analysing and comparing methods of earthquake-resistant building design, particularly the use of base isolation systems. It examines various types of isolators such as elastomeric rubber bearings, sliding base isolators, and spherical sliding isolators, evaluating their effectiveness in reducing seismic forces.

4. RESULT & DISCUSSION

The structural analysis of the proposed RCC building was carried out using ETABS. The analysis results were obtained in both graphical and tabular forms. The structural performance was evaluated mainly in terms of storey displacement, storey response, bending moment, shear force, beam deflection and column axial force.

4.1 Storey Displacement

The storey displacement of the building was evaluated using ETABS. The total height of the building is 19.8 m and the permissible

maximum storey displacement was calculated as 79.2 mm. The maximum storey displacement obtained from the analysis was 56 mm, which is considerably lower than the permissible limit. Hence, the structure satisfies the displacement requirement under the considered loading conditions.

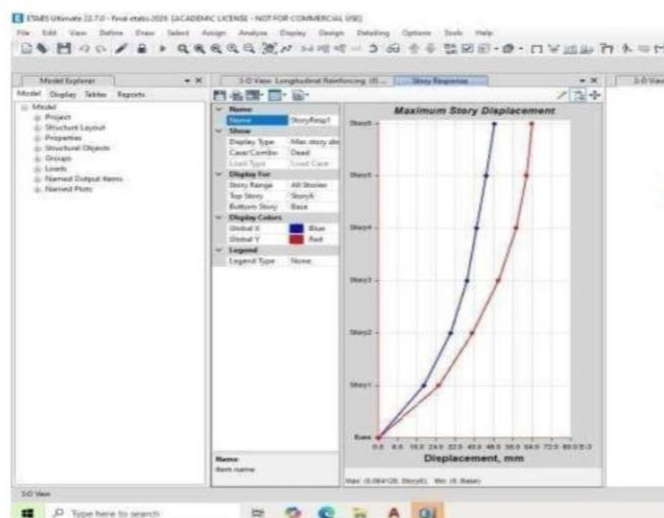


Fig. 1. Storey displacement diagram obtained from ETABS

4.2 Storey Response

The storey response spectrum plot was obtained from the ETABS analysis to evaluate the seismic response of the structure. The response plot helps in assessing the behaviour of the building under the applied earthquake loading and the variation of structural response along the height of the building.



Fig. 2. Storey response spectrum plot

4.3 Beam Response

The analysis of beams was carried out to determine the bending moment, shear force and deflection under the considered load combinations. The ETABS results provide the critical member forces required for the design and reinforcement detailing of the beams.

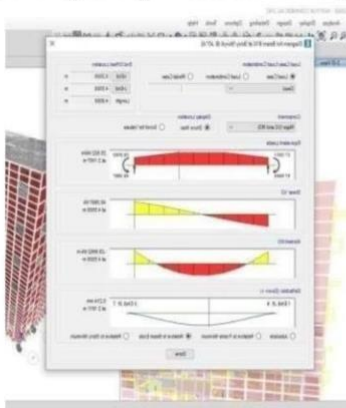


Fig. 3. Bending moment, shear force and deflection diagram of beam

4.4 Column Response

The axial force and other design parameters of the columns were obtained from the ETABS analysis. These analysis results were used to determine the required reinforcement and to check the adequacy of the structural members.

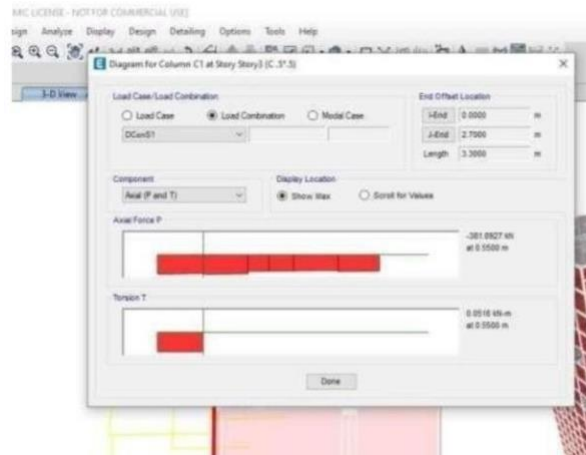


Fig. 4. Axial force and design result of column

4.5 Effect of Base Isolation

The comparative study between the fixed-base and base-isolated configurations indicates that the introduction of base isolation improves the seismic behaviour of the building. The isolators reduce the transmission of earthquake-induced forces from the ground to the superstructure. Lead Rubber Bearings (LRB) and High Damping Rubber Bearings (HDRB) provide flexibility and energy dissipation at the isolation level, thereby reducing the seismic demand on the superstructure.



Fig. 5. Comparison of fixed-base and base-isolated building response

The analysis results therefore indicate that the proposed base isolation system provides improved control of seismic response while maintaining the structural response within the required limits.

5 CONCLUSION

The project titled “analysis and design of earthquake resistant building using base isolation techniques” highlights the importance of advanced seismic protection methods in modern structural engineering. Through detailed modeling and analysis using etabs software, a comparative study was carried out between a conventional fixed-base structure and a base-isolated structure. The results clearly demonstrate that base isolation significantly enhances the seismic performance of buildings by reducing base shear, storey drift, and acceleration. The incorporation of isolators such as lead rubber bearings and high damping rubber bearings effectively decouples the structure from ground motion, thereby minimizing the transmission of seismic forces to the superstructure. This leads to improved structural stability, reduced damage, and increased safety of occupants during earthquake events. Although the initial cost of implementing base isolation systems may be higher, the long-term benefits in terms of reduced repair costs and improved building resilience make it a highly efficient solution. Overall, the study confirms that base isolation is a reliable and innovative technique for earthquake-resistant design, particularly suitable for buildings in seismic-prone regions, ensuring both safety and serviceability.

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