



Dynamic assessment of high-rise building using bearings in ETABS: Response spectrum analysis vs Time history analysis : A Review

Suchita Anil Ugale¹, Mr. Girish Joshi²

¹PG Student, Department of Civil Engineering, G.H. Raisoni College of Engineering and Management, Wagholi, Pune, Maharashtra, India

²Assistant Professor, Department of Civil Engineering, G.H. Raisoni College of Engineering and Management, Wagholi, Pune, Maharashtra, India

Abstract

This study article provides an overview of the investigation of high-rise structure dynamic performance through the application of both linear and nonlinear dynamic methods. In the current work, two distinct dynamic analyses a time history analysis and a dynamic analysis with response spectrum are examined for the dynamic assessment of high-rise buildings. With regard to the most recent Indian seismic code, a comparative assessment of the outcomes from the two distinct dynamic analyses is crucial. This study aims to evaluate how well lead rubber isolators reduce vibrations in a 26-story reinforced concrete framed building. In the first case, which involves a rigid jointed framed RCC structure, the structure is analysed using ETABS software. In the second case, lead rubber bearing (LRB) isolators are introduced. An isolator's effectiveness can be observed by comparing the storey drift, lateral displacement, base shear, acceleration, and maximum bending moment of the isolated base structure to those of the fixed base structure.

Keywords: Dynamic assessment, Response spectrum analysis, Time history analysis, Lead rubber bearing

Introduction

Steel and concrete frames are used in the majority of high-rise structures. Columns (vertical load-bearing elements), and beams (horizontal load-bearing elements) make up their frames. Shear walls or transverse bracing can be used to give the structural frame more lateral stiffness so that it can

withstand wind stress. In general, the foundations of tall buildings consist of underground concrete piles, piers, or caissons that withstand extremely high gravity loads. Nevertheless, the requirement that a high-rise structure be able to withstand lateral forces brought on by wind and possible earthquakes is the most crucial design consideration. Seismic and wind forces on a multi-story

building increase as the building height increases. To find out how a structure will react to an earthquake and to design structures appropriately, seismic analysis is required. The seismic analysis of building can be performed through various methods, such as time history analysis, displacement analysis, response spectrum analysis, and static seismic approach. Building resting on it will experience movement at its base. Although a simple basic isolator is effective in protecting buildings from seismic movements, it cannot always dissipate the energy received during an earthquake. Base isolation is the term used for installing flexible bearings or pads, which consist of layers of rubber and lead, between a building's foundation and the structure above. LRBs provide the benefit of prolonging a building's natural period beyond the seismic period range, thereby reducing amplification caused by earthquakes. Consequently, the utilization of LRBs presents an optimal approach for decreasing seismic loads. Lead was chosen for its ductile properties - although it can be deformed by earthquake movement, it returns to its original shape and can be deformed many times without losing strength.

Method of Analysis

As per IS: 1893 (part1) 2016 method of analysis of building for design earthquake.

(1) Equivalent static method

(2) Dynamic analysis method

Both the Response Spectrum Method (RSM) and Equivalent Static Method (ESM) seek to assess the seismic forces acting on a structure by applying a series of static forces at defined points. In the context of a design-basis earthquake (DBE), the forces calculated within the structural members and at the supports using either method closely

approximate (though with a conservative estimate) the actual forces experienced by the structure. It should be noted that while the force distribution calculated using either of these methods represents a set of equivalent static forces, an earthquake is a dynamic force. RSM is based on the first few natural periods, whereas ESM is based on the structure's fundamental natural period of vibration. This is the difference between the two methods. The accuracy of seismic load estimation is expected to increase with the consideration of a greater number of natural periods. Response-spectrum analysis, time-history analysis, and the computation of vibration modes using Ritz or Eigen vectors are examples of dynamic analysis capabilities for both linear and nonlinear behavior.

Literature Review

Ashikur Simon et al (2021) through modelling and analysing buildings with various shear wall configurations, the researcher conducted a study to determine the optimal orientation and placement of shear walls in RC structures to mitigate drifts and deflections. The findings suggest that incorporating shear walls can reduce lateral displacements, storey drift, construction time, and enhance structural stiffness. It is recommended to position shear walls in both the short and long directions, as evidenced by a comparison between models with shear walls only at the center and those at both the center and edges. When symmetrically positioned relative to the building's center of mass, shear walls demonstrate increased effectiveness, with peripheral shear walls showing superior performance.

N. Murota et al (2021) the lateral force procedures and historical analyses are conducted for the three chosen model buildings of varying heights, which were selected from a real building database within the presumed seismic zone. Building seismic

responses were assessed, and the effectiveness of the seismic isolation system was examined. The SI system and applicability of a Turkish residential HDR system were mentioned in the study's overall conclusion. The test results demonstrated that the insulation design was appropriate and performed adequately.

Iswandi Imran et al (2021) In alignment with the latest seismic regulations in Indonesia, he presented a case study on the layout procedure and overall performance assessment of reinforced concrete residences with base isolation utilizing double-concave friction pendulum (DCFP) bearings. Through nonlinear finite element analysis, the seismic performance of standard 10-story buildings with and without isolation under a maximum-risk earthquake (MCER) scenario in Jakarta, the capital of Indonesia, was investigated. The researcher came to the conclusion that it was possible to lessen projected losses from future earthquakes by enhancing the seismic performance of a floor-isolated building equipped with DCFP bearings. This would greatly lower the risk to the building's owner and make the surrounding area safer for both the building's occupants and the general public.

V. Naresh Kumar Varma et al (2020) an analysis of the building's shear wall was done in three dimensions. The effects of these openings' sizes and locations are covered in this study. The researcher found the opening's total deflection reduced as it moves up the storey level. When shear walls were added to a building, the displacement of storeys was reduced. Shear walls increase a building's resistance to earthquakes. In earthquake-prone areas, shear walls were recommended due to their enhanced resilience to seismic loads. When comparing the bottom story to the top story of a building, it was observed that the stiffness of the bottom story was

greater. Nonetheless, with increasing story height, the drift value experiences a notable initial decrease before gradually levelling off.

N Lingeshwaran et al (2020) this paper's primary goal was to compare how storey displacement and drift varied across various structures. The researcher noticed that during earthquakes, symmetric buildings fare better than asymmetric ones. The researcher discovered that symmetrical structures outperform asymmetrical ones in terms of performance. According to the results above, symmetrical buildings were less resistant to seismic loads than T-shaped buildings. In comparison to the top floor, the first floor's storey displacement was comparatively smaller. Additionally, the researcher discovered that symmetric buildings had a smaller displacement than asymmetric ones.

Shaikh Akhil Ahmad et al (2020) Explored through Response Spectrum Analysis was the utilization of shear walls at different locations within a multi-story residential building of G + 20 floors, examining the structural response to earthquakes. The maximum allowable displacement, torsional irregularity, base shear, and storey drift of the G + 20 multi-story building were thoroughly investigated. Employing the well-known Finite Element Method (FEM) integrated software known as Etabs 2015, the entire structure underwent analysis and simulation across all seismic zones of India, as outlined by IS 1893 (Part-1)-2016. In summary, he found that, when compared to seismic zones II, III, and IV, the maximum displacement and storey drift values for all three cases A, B, and C were higher in seismic zone V. This suggests that, by designing the structure with uniform stiffness, torsional irregularity resulting from load cases, can be reduced.

Donato Cancellara et al (2019) the researcher investigates the dynamic

performance of multi-story buildings characterized by significant design irregularities, particularly those employing base isolation. In this specific scenario, high damping rubber bearing isolators were utilized, arranged parallel to friction slider isolators. Both response spectrum LDA (RS) dynamic analysis and nonlinear dynamic analysis (NLDA) were conducted to evaluate the structure's response under diverse conditions. Notably, the response spectrum LDA (RS) dynamic analysis yielded less conservative results in terms of displacements compared to the nonlinear dynamic analysis (NLDA). It is essential to compare the study findings, particularly regarding displacements and stresses, in light of the recently adopted Italian seismic code NTC 2018.

Seung Yong Jeong et al (2019) the researcher evaluates the seismic performance of a 49-story residential building under construction in Seoul, Korea. This particular building, featuring an unconventional floor plan, shares a deep basement with neighbouring structures. The researcher examined several nonlinear time histories for the Rare Earthquake (RE) and Maximum Considered Earthquake (MCE). The researcher investigated the effects of basement modelling techniques.

Parham Shoaie et al (2019) in this study, the seismic design of steel moment frame structures isolated by lead-rubber bearing (LRB) devices was assessed using a reliability-based approach. The researcher introduced reliability curves for designing a bottom-isolated structure. These curves provide the target reliability and yield two key structural parameters: the natural period of the superstructure and the displacement of the target foundation. The proposed approach was suitable for seismic design of other structural systems with different isolation techniques until reliability curves were

developed using the proposed approach. The equation underwent calibration with an optimally designed set of systems, which were isolated from the base using a genetic algorithm. The proposed technique was demonstrated using a steel moment frame building located in Los Angeles, California.

Fabio Mazza et al (2018) Research has been undertaken to explore the influence of masonry infill on the seismic behaviour of reinforced concrete buildings. The nonlinear dynamic response of fixed-base structures, both with and without a soft storey retrofitted with a base-isolation system, has been investigated under near-fault ground motions to meet the performance criteria specified in the current Italian seismic code for high-risk seismic zones. Three structural configurations were compared using a six-story RC building as the experimental model: a bare structure with non-structural masonry infill's (BS case), a fully in filled structure with uniform masonry infill distribution (IS_R case), and a partially in filled structure with irregular masonry infill distribution (IS_IR case).

Mohan Irfan Khan et al (2018) stated that the G+15 storey RCC framed structure's lead rubber isolator's efficacy. Using data from the Bhuj earthquake, the structure was analyzed in ETABS software for two scenarios: one involved a rigid jointed framed RCC structure, and the other involved the installation of lead rubber bearing (LRB) isolators beneath India's most seismically active region, zone V, resting on loose soil (type III). In comparison to fixed base buildings, he noticed that base isolated buildings with LRB isolators take longer to complete. With an LRB isolator, the fixed base building time interval changes from 1.75 seconds to 3.94 seconds. He contrasted the base isolated building with LRB isolator's acceleration, story drift between floors, and reduction in maximum bending moment with

that of the fixed base building. Based on the data, he came to the conclusion that installing an LRB isolator as the base isolator reduced the building's seismic response and enhanced its performance during an earthquake, making it more appropriate for facilities that were most needed after the earthquake as well as for the retrofitting of significant structures.

Sahar Radkia et al (2016) the primary objective of the researcher's study was to investigate the behaviour of asymmetric sliding buildings utilizing steel moment frame systems under horizontal and vertical seismic loading, while considering the effects of soil-structure interaction. Nonlinear time history analysis was employed to compare the maximum absolute displacement, maximum absolute acceleration, maximum absolute sliding displacement, and maximum absolute sliding speed across the various models. The researcher advised to disregard the vertical component for buildings that are relatively high-rise.

Cenk Alhan et al (2016) the significance of HDRB stiffening in base-isolated buildings is investigated in this study through online real-time history analyses of benchmark six-story base-isolated structures. These structures were simulated with HDRBs using both non-stiffening and stiffening models. The analyses were performed considering synthetic near-fault ground motions as well as historical terrain-fault distances and magnitudes. The base for the comparisons is the nonlinear time history examined under the previously mentioned ground motion records using the stiffening and non-stiffening HDRB model. Peak floor accelerations, peak story drifts, and peak-based displacements are taken into account.

Manish Kumar et al (2015) the effect of cavitation on the axial and shear

characteristics of elastomeric bearings was investigated through post-cavitation testing. The empirical model of elastomeric tension, which was implemented in Open Sees, ABAQUS, and LS-DYNA, was verified using the test material. As the load cycles increase, the bearing's tensile strength before cavitation decreases. The amount of reduction depends on the previous maximum tensile strength value. The pre-cavitation tensile stress decreases as the parallel shear stress increases. The loading sequence does not change the behaviour of the elastomeric bearing under cyclic stress. Due to previous cavitation, no significant reduction in the flexural load of the bearings is observed.

Nadeem Hussain et al (2015) the suggested research allowed the researcher to assess various seismic design codes across different performance levels for a variety of reference buildings. This study provides valuable insights to aid designers in enhancing their designs in seismic regions by evaluating seismic performance and anticipating behaviour across various performance levels. As a result, this approach leads to a significant decrease in the quantity of structural steel utilized in similar buildings constructed under diverse standards.

Tobia Zordan et al (2014) the research offers an enhanced formulation for the linearization of structures supported by lead rubber bearings (LRB), compared to previous equations in the field. Ideal damping ratios were calculated and averaged over 12 ground motions, utilizing the concept of secant stiffness. These ratios were optimized to minimize the discrepancies in maximum displacement between equivalent linear (EL) analysis and nonlinear time history (NLTH) analysis. It was assumed that the bilinear hysteresis model had an LRB yield displacement of 1 cm. An improved equivalent viscous damping model was

developed based on the optimal damping ratios identified through the genetic algorithm.

Habib Saeed Monir et al (2013) the paper examines the dynamic performance of a newly developed friction damper, utilized in the diagonal bracing of structures. It consists of nine steel strips and nine high-strength steel bolts. The introduction of this modified energy absorber resulted in a significant decrease in lateral displacements and base shears of the multi-story building. Moreover, the damping system efficiently dissipated a substantial amount of energy. This damper not only improves structural stiffness but also acts as an effective dissipative device with impressive energy dissipation abilities. The integration of the modified friction damper led to reduced displacements and story drifts.

A. R. Bhuiyan et al (2009) The researcher examined the mechanical behaviour of high damping rubber bearings (HDRBs) under horizontal cyclic shear deformation, maintaining a constant vertical compressive load. Based on experimental findings, an elasto-viscoplastic rheology model of HDRBs for seismic analysis was developed. The numerical simulation results for sinusoidal loading presented demonstrate the ability of the proposed rheology model to accurately replicate the mechanical behaviour of HDRBs. This approach addresses the limitations of previous seismic analysis models relying on elasto-plastic hysteresis behaviour. Consequently, the current study aims to design a rheology model for HDR bearings that incorporates Mullins softening behaviour.

Nicholas D. Oliveto et al (2005) His work includes a group of two-way models that were created by joining a number of straightforward two-dimensional formulations. The bearing response at low, medium, and high stress levels is properly

described by the models using a single set of parameters, which were calibrated using a set of unidirectional test data. For validation, bidirectional shear-controlled tests from the literature are employed, and numerical simulations were run in a building that was isolated on a floor and exposed to both free vibration and bidirectional seismic stimulation. They were generated by merging together a number of straightforward two-dimensional models, and the testing was done by a series of unidirectional harmonic tests with strain amplitudes ranging from 5% to 200%.

A V Bhaskararao et al (2005) The researcher analysed the effectiveness of dampers in reducing displacement, acceleration, and shear forces between linked neighbouring structures, focusing on three structural responses. A parametric study was conducted to determine the optimal slip force for the dampers. Additionally, to reduce damper costs, the study investigated the best placement locations for dampers as an alternative to installing them at every floor level. It was observed that the numerical and analytical models yielded nearly identical seismic responses for the frictional force in the connected damper. The study revealed that friction dampers significantly reduce the seismic reactions of nearby connected structures. It was concluded that connecting two adjacent structures with dampers at every floor level is unnecessary; instead, installing fewer dampers at strategic locations can substantially decrease the combined system's seismic response. Furthermore, the researcher investigated whether the ultimate slip force of friction dampers could minimize the seismic reaction of two connected nearby structures..

Conclusion

In conclusion, STAAD Pro and ETABS are the most widely used structural analysis and design software programs. Around the world, structural analysis and design commonly use these two distinct tools.

- The use of bearings in ETABS for seismic analysis of high-rise buildings is an important field of study that makes a substantial contribution to the continuous efforts to improve the seismic resilience of structures.
- High-rise building seismic force mitigation has been shown to be significantly aided by the application of base isolation techniques, especially the use of bearings in ETABS.
- Buildings with base isolators installed have continuously demonstrated a decrease in accelerations and displacements during seismic events, which enhances the overall structural performance of the building.
- The goal of research has been to optimize base isolator design parameters such as shape, stiffness, and damping.
- The review has emphasized the potential of base isolators to improve multi-hazard resilience, in addition to seismic considerations. Structures with the appropriate isolators have shown enhanced performance in wind, blast, and other dynamic load scenarios in addition to earthquake scenarios.

By synthesizing the most important discoveries and developments in this area, this review has taken information from many studies and applications. Future studies should concentrate on resolving these issues and improving the

scope of buildings and geographic areas in which base isolation techniques can be applied.

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