Effect of Base Isolator on Seismic Force Reduction

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ABSTRACT:

Earthquakes pose a significant threat to buildings and infrastructure, resulting in extensive destruction and loss of life. Engineers and architects have devised novel techniques to improve the resilience of structures during earthquakes. This project centers on Base Isolator technology, comparing the seismic responses of analogous structures with and without Base Isolators. A base isolator is a device or technology that can significantly diminish seismic forces. The devices are engineered to ensure that these structures are protected against seismic effects. Typically installed between a building's foundation and superstructure, these devices serve as a buffer between the higher and lower sections of the structure, allowing for independent movement during an earthquake, thereby excluding ground influence. Base isolators have demonstrated efficacy in reducing the impacts of seismic occurrences and are extensively utilized in earthquake-prone areas globally. This study examines the impact of base isolators on irregular multistory buildings by doing seismic analysis using ETABS software. The comparison of the effects of base isolators on story displacement, drift, story shear, overturning moment, lateral load, and response spectrum curve of various irregular multistoried structures with their non-base isolated counterparts indicates the potential of base isolators to enhance the resilience of existing buildings and infrastructure in earthquake-prone regions.

Keywords: Seismic resilience, Seismic Force, Base Isolator, ETABS, Drift, Response Spectrum, Storey Shear

1. Introduction

When energy is abruptly released in the Earth's crust, earthquakes occur, impacting structures through seismic waves. The magnitude of these effects is contingent upon wave type, architectural design, construction quality, and local geological factors. Non-structural and Structural damage to the building resulting from the earthquake. Load-bearing elements include beams, columns, and shear walls, which can lead to partial or complete collapse. Non-load-bearing elements, such as partitions, ceilings, and facades, are structurally independent of the building, resulting in non-structural damage that may jeopardize occupant safety and impair functionality. Nonetheless, earthquakes can result in foundation damage through soil settlement or liquefaction, both of which compromise the structural stability of the building's foundation. Comprehending the structural behavior of high-rise buildings (exceeding 15 stories) is essential for resilience. This article examines the influence of lateral pressures, including seismic forces, on "Super Tall Buildings" (300m—600m in height). The use of a base isolator, a device situated between the foundation and the building's superstructure, is an essential technique for mitigating seismic stress. Base isolation absorbs seismic forces, so safeguarding the building. This technology mitigates seismic forces, allowing the foundation

to shift during an earthquake while the superstructure remains stationary. The application of smooth rollers added between base isolators creates independent movement between the foundation and superstructure along with various implementation options. The seismic displacement that affects the superstructure remains limited through this method.

Seismic forces enter the structure when flexible joints are used. The base isolation system makes use of bearings that enable horizontal movement yet maintain their horizontal stiffness throughout displacement. The bearings enable the reception of vertical and horizontal forces in these components which strengthens both superstructure and foundation isolation systems. The large superstructure movements occur because the base isolation system shifts independently from an unmoving foundation. The system foundation isolators are produced from multiple materials that generate different seismic force responses. The structure accepts incoming seismic energy from the ground which base isolators and seismic dampers convert into reduced movements relative to their base. Scientific research continues to develop ways for base isolators to better reduce seismic forces.

The research by Monika Rajendra et al. [1] conducts a review of base isolation systems to evaluate the performance difference between fixed-base and base-isolated structures based on soil conditions. The reaction on rigid strata produces favorable results yet soft soil intensifies ground acceleration by reducing energy dissipation and causing structures to vibrate at increased frequencies. The performance of low to medium-height buildings remains effective with the isolators while changes in isolator type due to material variations affect the structural response. Lin Su et al. [2] created a new base isolator that integrates sliding resilient base isolation system (SR-F) characteristics from both the EDF base isolator (Electricity de France) and resilient base isolator (R-FB1). The research analyzed the response characteristics of the novel isolator alongside the R-FB1 isolator system, EDF system, and fixed base system. Results were measured for base shear together with spectral acceleration and spectral displacement during various earthquake conditions. Scientific testing of the SR-F isolator occurred through numerous earthquake event recordings. Base movement of less than 0.2 inches occurred as the SR-F isolator application led to 50 percent peak response decreases in both EDF and RFB1 systems. A subdued response was recorded for the maximum reaction between frequency and amplitude measurements.

A.N. Lin et al. [3] reported the results of seismic analysis for various base isolation and fixed base frame designs with rigid bases as well as base-separated concentrically braced and special moment-resistant steel frames in accordance with multiple standards of practice. The design base shear followed recommendations from the 1990 Structural Engineering Association of California (SEAOC) to construct fixed base frames. Test forces equivalent to 100%, 50% and 25% of SEAOC guidelines were applied to study the behavior of the base-isolated structure. A total of 54 different ground motion records were employed in the investigation. The investigation studied frame failure plus total roof displacement through a nonlinear time history analysis for particular components and frames. The implementation of lateral forces at 50% SEAOC recommendation leads to better performance alongside better compatibility results compared to different possible combinations. A research study evaluated peak response performance between fixed steel frames and moment-braced steel frames with base isolation. Boya Yin [4] studied the effects of soil-structure interaction as part of his research work. He established an isolated linear soil model as part of a linear state-space system. The response to transient earthquakes occurred through a non-linear system using time-step calculations from ground motion registers. The research investigated near-ground soil conditions by looking at soil compliance and behavior as distinct elements of investigation. Highly hysteretic friction forces increased the challenge of reaching seismic isolation targets.

Base isolation systems resulted in substantial building displacement higher up since they separated the base from the ground. Researchers examined the SSI effects through a nonlinear liquefaction model which demonstrated various aspects such as base shear and peak ground acceleration (PGA) and peak ground velocity (PGV) relative to an isolated base structure. Erickson et al. [5] conducted research to determine how an industrial structure reacted to seismic forces under IBC design standards. The superstructure performed elastic behavior under dynamic loading conditions. The research established that one isolation slab provided protection to three industrial buildings while researchers examined every aspect from design to analysis to position determination for the isolator.

Base-isolated structures receive substantial benefits from base-isolation methods as Naveena K and research colleagues [6] explain in their report. Base isolation serves as a powerful protection strategy for different built structures including buildings and bridges together with airport terminals and nuclear power facilities. The fundamental function of base isolation systems is to secure superstructure movement independence regarding foundations which leads to reduced internal stresses on beams and columns additionally minimizing both relative story displacements and drift. This design approach leads to decreased level acceleration forces which simultaneously lowers lateral loads while decreasing inertia forces. The base-isolated construction method reduces both overturning moments and shear forces within structural levels. Seyed Behzad Talaeitaba and his team researched the effects that seismic base isolation brings to reinforced concrete structure design criteria [7]. Our team studied 24 buildings that had different height levels including 8-story, 12-story, 20-story and 24-story structures situated at four locations. The examination of buildings included standard, intermediate and specialized swing frames and fixed base structures which used corresponding frame types within their categories. The structure employed either conventional sway frames with ordinary shear walls or intermediate sway (special) frames together with specialized shear walls within its lateral load-resisting system. Yao Domadzra et al. [8] studied base isolation systems by evaluating the main seismic attributes of Lead Rubber Bearings and Friction Pendulum System isolators. Various aspects influencing the success of base isolation devices were analyzed in detail by the authors who compared structural seismic reactions between different isolator types while under dynamic system stress. Anil Kumar et al. [9] studied base isolation applications in multi-story buildings while noting that soil type controls the performance of fixed base and isolated systems. The ground surface produces elevated acceleration rates as it loses its energy-absorbing capabilities while raising its oscillating frequency. The reaction remains satisfactory when dealing with rigid strata. The building structure reacts according to changes in the characteristics of isolators that successfully serve low to medium-rise buildings.

A research work titled "Advancing Seismic Performance: Isolators, TMDs, and Multi-Level Methods in Reinforced Concrete Structures" was released by Fadhil A. Jasim and colleagues during [10]. This assessment examines multiple earthquake mitigation methods consisting of Tuned Mass Dampers (TMD), double sliding pendulums (DSP), high-damping rubber bearings and lead rubber bearings within different earthquake intensity levels and building heights. The research presents a new kind of seismic isolation enhancement technique through the combination of multi-level TMDs with multi-level isolation methods. The research shows that using multiple isolation layers or multiple TMD levels produces superior results because four layers of isolation lead to an 80 percent BS reduction for high-rise buildings. A system featuring a four-level TMD delivers better performance than a single top-story TMD because it reduces base shear by 44.5% while the top-story TMD only achieves a 26.6% reduction. A.B.M. S. Islam et al. [11] studied Lead Rubber Bearings (LRB) and High Damping Rubber Bearings (HDRB) effects on

Dhaka structures through SAP2000 software analysis. Building isolation systems act as effective elements to decrease seismic stress during natural events. A non-linear liquefaction model served for SSI assessment which demonstrated its effects relative to an independent foundation structure by means of base shear distribution together with peak ground acceleration (PGA) and peak ground velocity (PGV) parameters. Industrial structures underwent seismic force response testing according to IBC design requirements as Erickson et al. [5] reported. Dynamic stress caused the superstructure to demonstrate elastic response behavior. Researchers found that one isolation slab enabled the support of three industrial structures while they meticulously studied the slab design aspect along with analysis and positioning.

2. Base Isolators

The fundamental concept is to enhance a building's responsiveness, enabling it to withstand ground movement without transmitting vibrations to its structure. Ideally, an optimal system would achieve full separation; nonetheless, the structure must invariably maintain contact with the earth in some manner. A completely rigid structure would have zero displacement relative to the ground, meaning no relative movement would occur as the ground shifts, as the structure would experience the same acceleration as the ground. Nevertheless, a completely adaptable building ought to possess an indefinite lifespan, and the relative displacement between the structure and the ground will be analogous to ground displacement, with no acceleration occurring within the structure. In actuality, no structure is entirely stiff or completely flexible, and hence, it will be subjected to ground vibrations that lie between these two extremes. The maximum displacement and acceleration in relation to the ground, during an earthquake, will vary depending on the earthquake's characteristics.

2.1 Objectives of the Study

a) To assess the performance of various types of base isolators through simulations and real-world case studies

b) To carry out a cost-benefit analysis to compare initial costs and long-term savings from reduced damage and repair needs

c) To develop design guidelines and optimization strategies for implementing base isolation in different building types and soil conditions

d) To review and suggest improvements to existing building codes and standards to promote the use of base isolation

e) To increase awareness among architects, engineers, and building owners about the benefits and limitations of base isolation technology

By studying and implementing base isolation systems, we can significantly enhance the resilience of buildings to earthquakes, ensuring the safety of occupants and reducing economic losses.

2.2 Components of Rubber Base Isolators

Rubber base isolators comprise the fundamental components: a lead plug and rubber typically arranged in layers.

Rubber: As rubber can move and then return to its original place, it offers flexibility. The rubber bearings will gradually move a building back into place if it hasn't already done so after an earthquake. This may require months, but it will revert to its former location.

Lead: Because of its large bulk, a structure may continue to wobble on its isolators following a powerful earthquake. Base isolators were equipped with lead cores as a means of dissipating energy. Lead was selected due to its plasticity; even though it can distort during an earthquake, it will always return to its former form and can deform repeatedly. Thus, the lead converts the kinetic energy of the event into thermal energy, maintaining its integrity. When an earthquake occurs, the lead undergoes deformation.

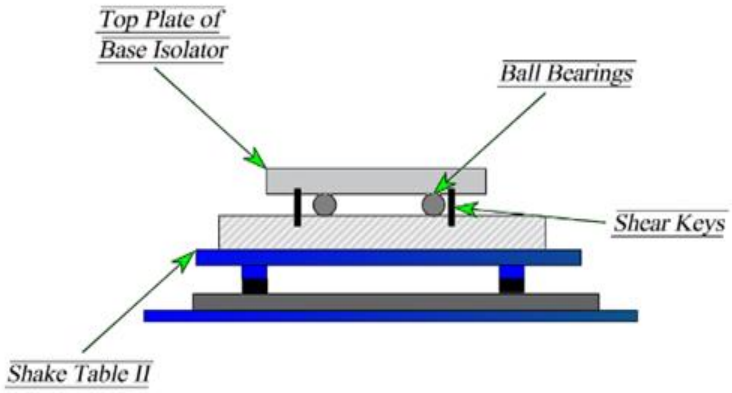

Fig.1.Base Isolation System

2.3 Benefits of Base Isolators

a) Base separation shields buildings not just from seismic activity but also from GSA blast loads since it allows for mobility, which lessens the explosion's overall effect on the buildings.

b) Because base-isolated structures can be predicted, their reliability is far higher than that of traditional structural elements.

c) It is necessary to use reinforcing techniques like shear walls, bracing, and frames to lessen the stresses from earthquakes that are transferred to the structure. Seismic analysis is made simpler by allowing for a reduction in structural elements when compared to traditional structures.

d) Damage is only concentrated in isolation systems, where components are readily interchangeable, in the event of significant, unanticipated earthquake activity.

e) It is also possible to adapt base isolation into appropriate pre-existing structures. Furthermore, the structure can continue to be used while construction is underway.

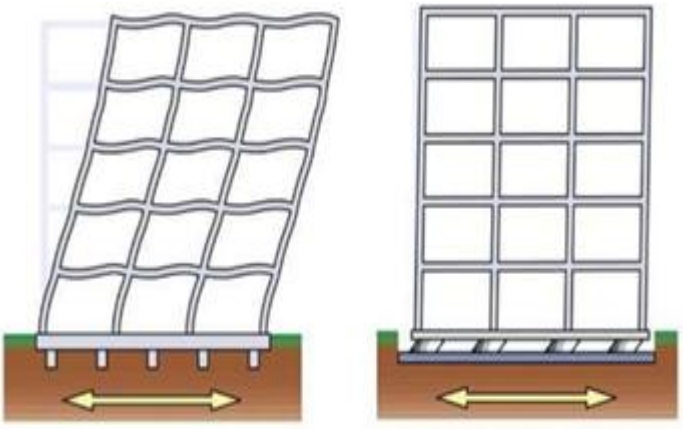

Fig.2. With or without a Base Isolation System during a Seismic Event

2.4 Limitations of Base Isolators

- Base isolation is not applicable to all structures; for instance, it is unsuitable for those situated on soft soils.
- Its effectiveness diminishes in tall structures.
- In contrast to previous retrofitting methods, the structure cannot have partial application of base isolation.
- It is tough to implement inefficiently and often requires highly educated engineers and laborers.

3. Introduction to ETABS

The structural analysis and design program is ETABS (Extended Three-dimensional Analysis of Building Systems), created by Computers and Structures, Inc. (CSI). This tool is intended for the analysis and design of building systems, offering robust modeling and analytical capabilities for engineers and architects.

Working Process

Model Creation

Utilizing a graphical interface, users can delineate intricate architectural models incorporating geometry, materials, and loads, among other elements. ETABS provides tools for establishing grids, importing CAD files, and producing 3D models.

Load Application

These building models can accommodate numerous types of loads, including dead loads, live loads, wind loads, and seismic loads. ETABS incorporates automated load creation for diverse code requirements.

Analysis

The software conducts linear and nonlinear static and dynamic analyses, encompassing response spectrum analysis, time-history analysis, and pushover analysis. It also computes internal forces, displacements, and stresses via Finite Element Analysis (FEA).

Design

ETABS facilitates the design of diverse structural elements, such as beams, columns, slabs, walls, and foundations, in accordance with international building rules and standards. The results are comprehensive and assess conformity.

Results Interpretation

The software provides comprehensive visualization choices for analyzing and interpreting findings, including deformed forms, contour plots, and full reports. Users can evaluate and revise the analysis results.

3.1 Advantages

(a) Comprehensive Analysis Tools: ETABS provides a comprehensive array of analysis capabilities, encompassing static, dynamic, and nonlinear analysis.

(b) User-Friendly Interface: The graphical interface is straightforward, facilitating effortless model generation and modification.

(c) Integration with Design Codes: The program accommodates a range of international design codes, assuring adherence to local standards.

(d) Detailed Visualisation: Advanced visualization tools assist users in interpreting results and making educated design decisions.

(e) Efficiency: Automated techniques for load application, analysis, and design diminish the duration required for structural analysis and design.

3.3 Disadvantages

a) Cost: The expense of ETABS can be considerably elevated, rendering it inaccessible for small organizations or individual practitioners.

b) Learning Curve: ETABS has an intuitive user interface, but mastering its comprehensive features and functionalities may require considerable time and training.

c) Hardware Requirements: Even with software, large and intricate models can be resource-intensive and operate inefficiently without a robust computer.

4. Terminology

4.1 Storey Shear

Storey shear refers to the total horizontal force acting on a particular storey of a building due to lateral loads such as wind or seismic forces. It is the cumulative force that must be resisted by the structural elements at each storey to prevent lateral movement and ensure the building's stability.

4.2 Storey Drift

Story drift is the relative horizontal displacement

between two floors of a building due to lateral stresses, such as those from an earthquake.

This idea is crucial in structural engineering and seismic design since it enables the comparison and assessment of a building's reaction to lateral loads, as well as its stability and safety during seismic occurrences. Minimizing damage to non-structural materials and maintaining structural integrity during earthquakes is crucial for improving story drift control outcomes. It measures how much one floor moves laterally relative to the floor below it. The drift may be calculated as

Relative movement=Δ2–Δ1

Story height = H2

Hence, Storey Drift = $\frac{(\Delta 2-\Delta 1)}{H2}$

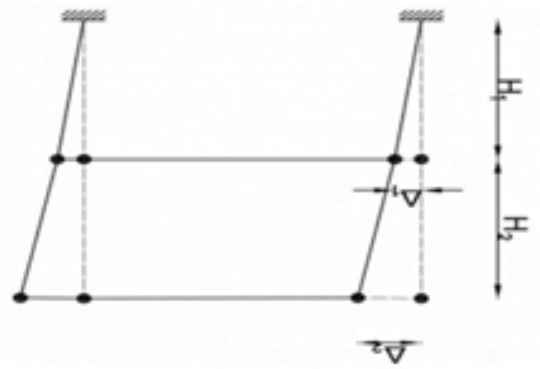

Fig.3. Storey drift details

4.3 Mass Source

The mass of the structure is to be specified in the Mass Source, along with extra dead and living loads that must be included for the earthquake analysis. Clause 7.3.1 of IS 1893:2016 (Part 1) states that the whole dead load plus a proportion of the applied load, as shown in Table 10, must be used to estimate the seismic design force.

(i) For the Imposed load distributed uniformly on the floor, 25% of the imposed load shall be considered when the intensity of the live load is up to and including 3.0 kN/m².

(ii) (ii) For imposed load distributed uniformly on the floor, 50% of the imposed load shall be considered when the intensity of the live load is more than 3 kN/m².

4.4 EQX & EQY

Exterior forces from earthquakes appear as EQx and EQy along the directions of the x-axis and y-axis respectively. The assessment of building seismic response depends on EQx and EQy as crucial factors that protect safety while maintaining structural integrity in a 15-story building.

The seismic forces acting parallel to the horizontal building axis are shown by the data point EQx. Selucid expresses external forces that match the seismic wave-propagation effects along this direction.

EQy signifies seismic forces that operate at right angles to the y-axis in horizontal orientation. The horizontal seismic loads originating from seismic events exist orthogonal to EQx.

4.5 Structural Response:

Seismic force response analysis along the x and y axes should be conducted to check for stability and avoidance of collapse. Building movement under forces requires a calculation of its expected displacement and sway.

Dynamic Analysis:

The assessment of structures for seismic activity mostly utilizes dynamic methods between Response Spectrum Analysis (RSA) and Time History Analysis (THA) to learn about the structural response to EQx and EQy movements. Structural analysis methods enable researchers to assess seismic force involvement with various building levels and construction parts.

4.6 Modal - Mode and Diaphragm

Modal relates to the modes of vibration that the structure can experience during seismic activity. Each mode corresponds to a natural frequency and shape of vibration. In seismic analysis, mode refers to the different patterns of deformation that a structure can undergo when subjected to dynamic loads like those from an earthquake.

In structural engineering, a diaphragm is a horizontal structural element, like a floor or roof, that transmits lateral loads to the vertical resisting elements (like walls or frames). It plays a crucial role in the seismic performance of buildings.

Seismic Activity

Seismic activity refers to the frequency, type, and size of earthquakes experienced over a period in a specific area. It encompasses the generation, propagation, and effects of seismic waves produced by the sudden release of energy in the Earth's crust, often due to tectonic movements or volcanic activity.

4.7 Dampers

The reduction of seismic energy absorption and structural stability enhancement throughout earthquakes happens through the installation of dampers in buildings. Different types of dampers exist as viscous systems along with friction and tuned mass devices. Dampers use force redirection and heat generation to reduce building movements thus protecting buildings against destruction while maintaining operational safety.

4.8 Natural Frequency and Base Shear

The natural resonance rate that characterizes the movement of a building after being disturbed. Building resistance to vibrations determines natural frequency because it determines seismic wave resonance which can intensify both displacements and stresses. The total lateral force acting on a building foundation which exists because of seismic movements is what defines base shear. All lateral forces that operate on the building's mass to produce base shear include those from earthquake ground motions. Base shear represents an essential seismic design factor that engineers use to establish necessary design forces along with structural detailing specifications that protect buildings from dangerous seismic loads.

4.9 Seismic Load

The earthquake-induced forces that act on a building in lateral directions constitute seismic load. The ground shaking generates these forces which serve as crucial parameters for both analyzing seismic structures and designing such buildings for earthquake resistance.

4.10 Seismic Isolation System and Efficiency

The protection of a building against earthquakes involves the implementation of base isolators as well as dampers. Base isolation joins forces with dampers to protect buildings by providing separation from ground disturbances and energy dissipation in order to enhance their resilience. The ability of base isolation systems to lower seismic forces that reach a building defines their seismic isolation efficiency. The isolators perform an assessment through quantification to minimize building reaction when faced with ground shaking thus improving structural stability and reducing potential damage. Better isolation performance is achieved through higher efficiency which leads to safer buildings that operate during earthquakes.

4.11 Dissipation

Energy dissipation is a process that transforms seismic energy taken up by structure-connected devices into thermal energy or another kind of energy that reduces structure movement while protecting against seismic damage. The system increases the structural resilience by smoothing down the flow of additional energy preventing it from damaging structural stability.

4.12 Modal Analysis

Mode-superposition utilizes modal analysis to perform linear dynamic response through the analysis of free-vibration mode forms that enable displacement pattern description. Free vibration will cause structures to move toward

defined mode shape configurations. The main issue that appears with lateral displacement remains the most prevalent problem. Mathematical expressions of lower orders in mode shapes drive most of the structural reaction. The share of influence decreases while the prediction accuracy suffers when the number of orders increases. It becomes reasonable to conclude the analysis when enough mode shapes are generated. Many degrees of freedom in a structural system yield matching mode forms that are also equal to its N degrees. A separate normalized displacement pattern constitutes each mode shape which may be magnified and superimposed to create a new displacement pattern as shown in Fig. 5.

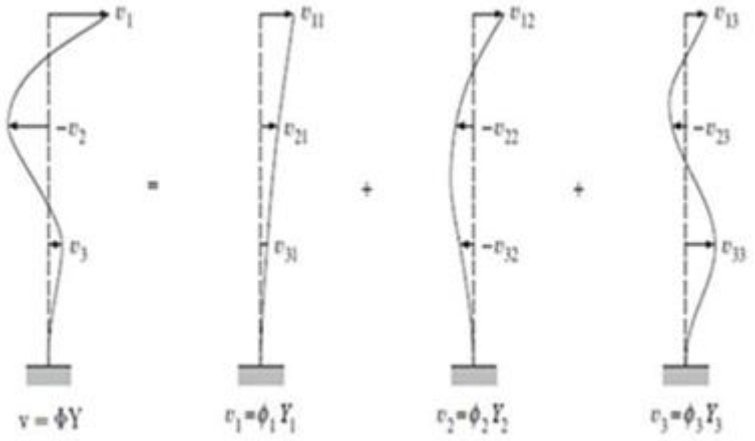

Fig. 4. Resultant displacement and modal components

4.13 Torsional Response

Torsional response refers to the rotational movement or twisting of a building around its vertical axis in response to lateral forces, such as those generated during seismic activity. It occurs due to irregularities in mass or stiffness distribution along the building height or asymmetrical loading conditions. The torsional response can affect the building's stability and structural integrity during seismic events and is crucial to consider in structural design to ensure balanced and controlled responses 24.

4.14 Resonance

When external forces apply pressure on structures they vibrate based on their own natural frequency under a condition called resonance. The natural frequency of a structure will amplify external force vibrations when their matching frequencies occur. Building safety relies heavily on preventing resonance since this measure helps reduce the response magnitude and structural damage throughout earthquakes.

4.15 Spectral Acceleration

The maximum acceleration response of structures during an earthquake appears at specific vibration periods in different parts of the response spectrum. Structures can determine their susceptibility to ground motion strengths at different frequencies through this quantitative measurement which supports seismic performance assessments.

4.16 Peak Ground Acceleration (PGA)

Peak Ground Acceleration (PGA) means the maximum acceleration measurement that occurs at surface elevation during earthquake occurrences. Seismic hazard analysis together with structural design fundamentally depends on this measurement which signifies the most intense shaking felt on the ground at any specified location. The measurement of PGA occurs in gravitational acceleration units (g) which aids engineers to evaluate seismic danger zones and create structural designs that can endure ground motion stress.

4.17 Equivalent Lateral Force Procedure

A building utilizes the Equivalent Lateral Force (ELF) procedure as a simplified design method that determines the lateral earthquake forces that

buildings need to withstand. The procedure analyzes forces according to a horizontal distribution across each floor while considering the mass characteristics and dynamic properties of the entire structure. Building codes including the International Building Code (IBC) contain the definition of ELF which serves as a working strategy to make structures earthquake-resistant.

4.18 Performance-Based Design

As an engineering approach Performance-Based Design (PBD) concentrates on building design for reaching specified performance targets under different seismic threat levels. Structures under PBD evaluation substitute traditional prescriptive code mandates with performance assessments which include safety requirements and functionality and damage restriction objectives. Resourceful analysis using nonlinear dynamic analysis determines earthquake performance while performance targets get developed specifically for structures based on their importance and occupancy status. The purpose of PBD is to enhance seismic resistance capabilities through financial and social benefit evaluation.

5. Method of Analysis

5.1 Response Spectrum Analysis

The evaluation system uses building reactions from every possible response type. Building codes demand multireaction analysis unless the structure belongs to a basic or highly detailed category. Different structural response types can work together in a single analysis. A computer system finds the different ways a building reacts under load. A simulation combines each unique response shape and its maximum force or acceleration value taken from the design spectrum. The method requires finding the strength of forces in each direction to determine building results. The method contains multiple combination rules for the design.

- Absolute-peak values are added together.
- The square root of the sum of the squares (SRSS)
- Complete Quadratic Combination (CQC)

5.2 Time History Analysis

This method involves solving the multi-degree-of-freedom equations of motion step-by-step in the time domain, which simulates a building's real response. It is the most advanced analysis technique that a structural engineer may use. The seismic ground motion that is chosen as an input parameter for a particular building directly affects the solution. Usually, the scope of this analysis technique is not to assign lateral forces directly, but rather to verify whether assumptions established during the design of significant structures are still appropriate.

6. Methodology

6.1 Frame configuration

Table1: Basic Configurations

Sl. No.	Type of Material	Specifications
1.	Concrete	M30
2.	Steel	Fe500
3.	Beam	350x350mm
4.	Column	450x450mm
5.	Slab	150mm
6.	Base Isolator	Rubber Base Isolation

6.2 Data for modeling the structure

The key features required for the configuration of the structural model are given in Table 2.

Table 2: Key Features of the Structural Model

Sl. No.	Name	Data
1.	Type of structure	R.C.C. frame
2.	No. of stories	G+15
3.	Floor Height	3m
4.	Bay Distance	5m
5.	Dead loads • Beam • Column • Slab	 3.06KN/m 5.06KN/m 3.75 KN/m^2
6.	Live load on Slab	3KN

7. Procedure of design analysis of the structure in ETABS

a. Establish the project

In ETABS, establish the project's structural system, number of stories, span lengths, story heights, and other pertinent details.

b. Define the material properties

List the qualities of the reinforcement steel and concrete in accordance with the BS code. This comprises the yield strength of steel (fy), the characteristic compressive strength of concrete (fck), and other material characteristics.

c. Describe the loads

According to the specifications of the IS code and the project's location, enter the dead loads (the structure's self-weight and any superimposed dead loads), live loads, wind loads, and seismic loads (if any).

d. Build the structural model

Using ETABS, model the beams, columns, slabs, and other structural elements, making sure that the geometry, connection, and support conditions are as realistic as possible.

e. Assign properties to the section

Based on the original design assumptions or prior experience, determine the cross-sectional dimensions and reinforcing specifications for the beams, columns, and slabs.

f. Apply the loads

Apply the specified loads—such as wind loads on the vertical elements and gravity loads on the slabs—to the relevant structural elements.

g. Examine the structure

Use ETABS to do an analysis to find the internal forces (axial, shear, and bending moments) in the structural parts.

h. Design the reinforcement

To design the reinforcement for the beams, columns, and slabs, follow the guidelines provided by the BS code. This includes figuring out how much longitudinal and transverse reinforcement is needed, making sure the design meets the code's criteria for strength and serviceability, and detailing.

i. Examine the layout

Check that the strength, serviceability, and detailing criteria of the BS code are met by the designed reinforcing details. In order to optimize the member sizes and reinforcement schemes, this may need iterative design procedures.

j. Produce the design outcomes

Create design reports, schedules, and drawings that detail the RC structure's final design,

including member sizes, reinforcing specifics, and other pertinent data.

7.1 Modelling

Defining materials, sections, diaphragm, load cases, mass source and Time history and Response spectrum functions

7.2 Drawing

- Assigning supports, load, diaphragm and mesh
- Defining load combination
- Model check before analysis and running the analysis

7.3 Analysis

Lateral loads, maximum story displacement, maximum story drifts, story shears and overturning moments

7.4 Model Images

The analysis focuses on four distinct types of G+15-storey buildings. Each is distinguished by the number of bays and floors at the top and bottom. The model numbers for the four distinct G+15 storey building types are listed below:

a) 1505100204

b) 1507080204

c) 1509060204

d) 1511040204

Table3: Models Descriptions

Sl. No.	Model Code Name	Structure Details			
		Floors		Bays	
		Top	Bottom	Top	Bottom
1.	1505100204	05	10	02	04
2.	1507080204	07	08	02	04
3.	1509060204	09	06	02	04
4.	1511040204	11	04	02	04

The pictures of the 3D- Extrude view as well as the Elevation view and Plan view of the bottom & top part of these four buildings respectively given below

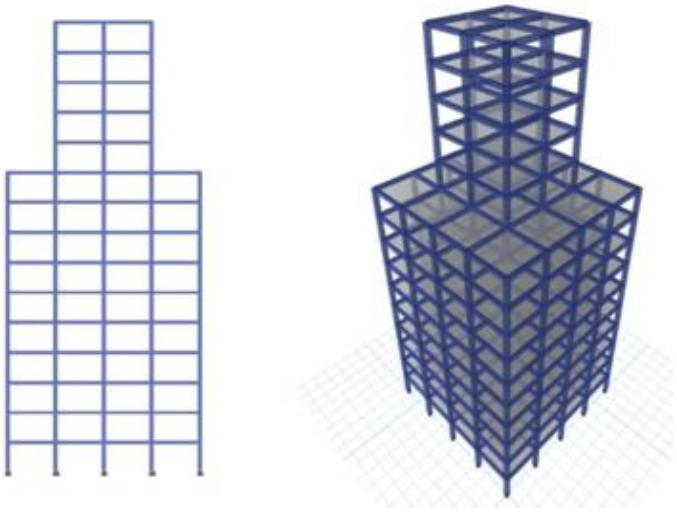

Fig.5. Elevation view of the structure & 3D view of Model No 1505100204

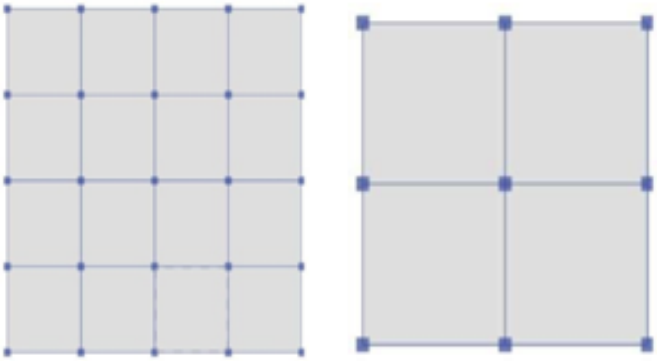

Fig. 6. Plan view of the bottom 10 4x4 bays & plan view of the top 05, 2x2 bays

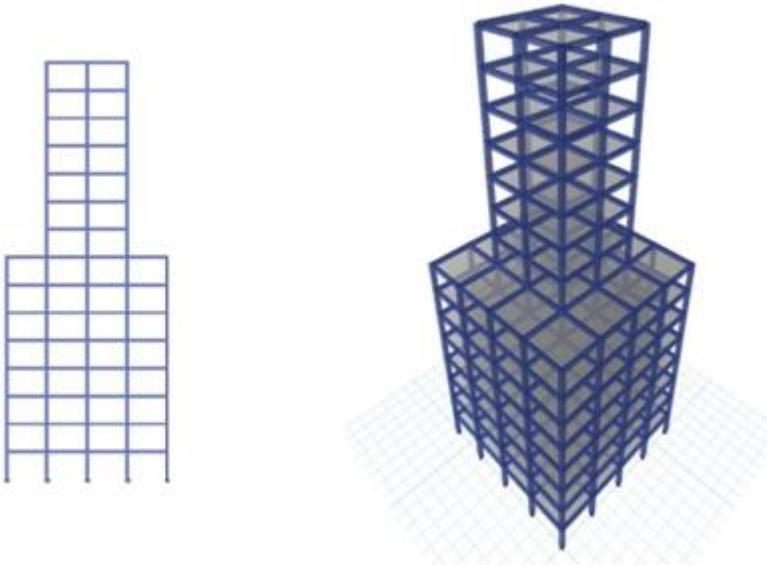

Fig. 7. Elevation view of the structure & 3D view of Model No 1507080204

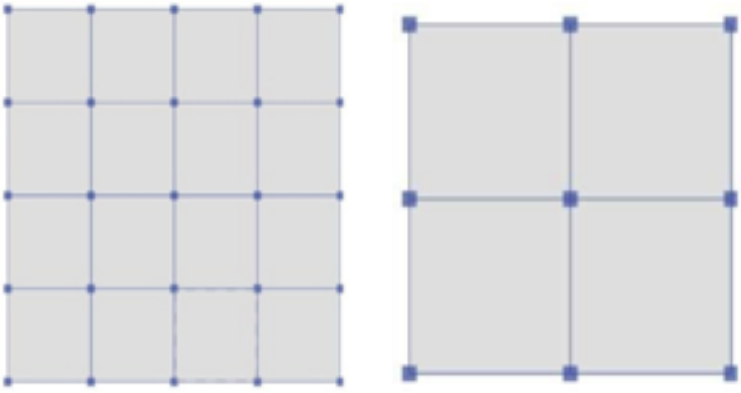

Fig. 8. Plan view of the bottom 08 4x4 bays & plan view of the top 07, 2x2 bays

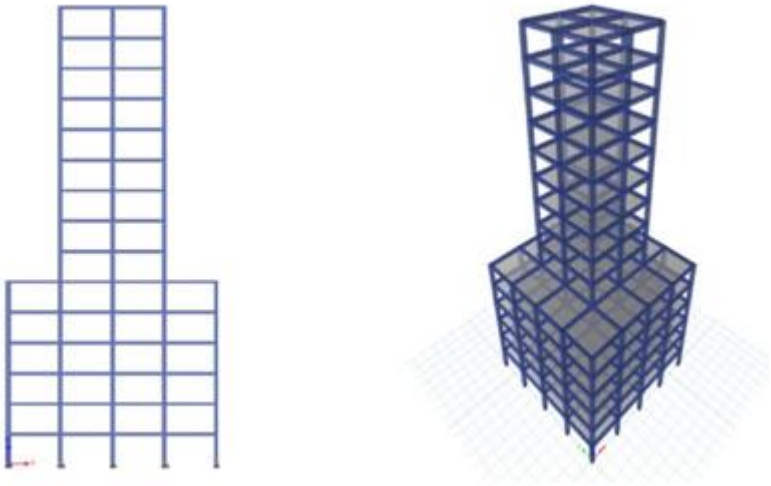

Fig. 9. Elevation view of the structure & 3D view of Model No 1509060204

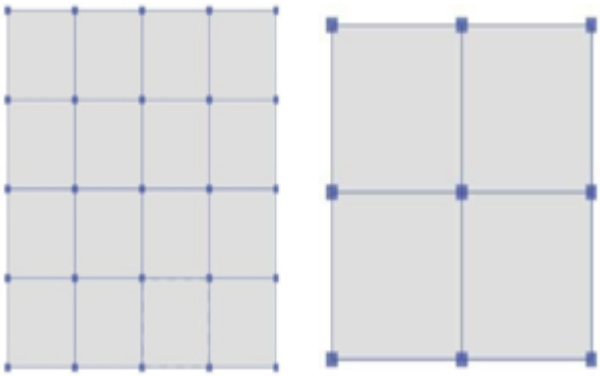

Fig. 10. Plan view of the bottom 06 4x4 bays & plan view of the top 09, 2x2 bays

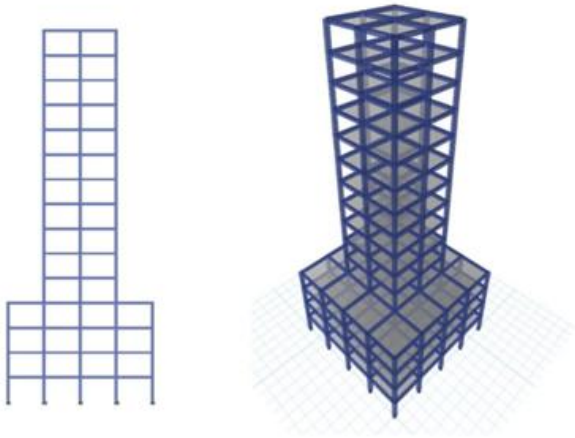

Fig. 11. Elevation view of the structure & 3D view of Model No 1511040204

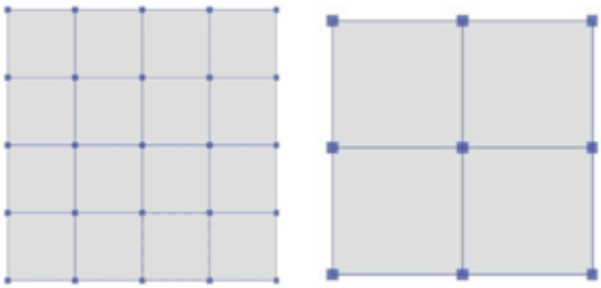

Fig. 12. Plan view of the bottom 04 4x4 bays & plan view of the top 11, 2x2 bays

8. Observation

In this analysis of structure with and without Base Isolators, a number of observations were made:

The structure performs better with base isolation systems than it does with a fixed basis.

When comparing the base-isolated structure to the fixed base structure, a significant reduction in frequency was observed.

Base-isolated structures did not exhibit any inter-storey drifts, whereas mass irregular structures did exhibit a significant amount of inter-storey drifts.

Because base isolation buildings have a longer time period and less acceleration acting on the structures, their base shear, relative drift, and torsion values are comparatively lesser than their non-isolated counterparts.

The prolonged period for a structure with an isolated base helps ensure the structure is totally independent of the earthquake's resonance region.

When subjected to seismic loads, deflection is less in base-fixed buildings than in base-isolated buildings.

Top-floor absolute acceleration, inter-storey drift, and base shear are significantly lower in base-isolated buildings than in fixed-base buildings, indicating a reduction in seismic forces in the structure and ensuring the safety of the building's structural and non-structural components.

Special considerations need to be taken into account when designing a structure for Base isolators using Building codes.

If a structure is fitted only with Base isolation and no mechanism is installed to dampen and reposition the structure to its initial orientation, then the effect of base isolation decreases due to a reduction in the allowable movement plane.

Installation of Base isolators is a highly technical procedure and can increase the cost of construction.

The following observations were plotted in a graph after the analysis of the structure with and without base isolators:

a) Storey displacement due to earthquake forces

b) Maximum Storey drift

c) Storey Shear experienced by the building due to earthquake force

d) Lateral Load acting on the structure due to seismic forces

e) Overturning moment of the structures

f) Response Spectrum curve of the structures

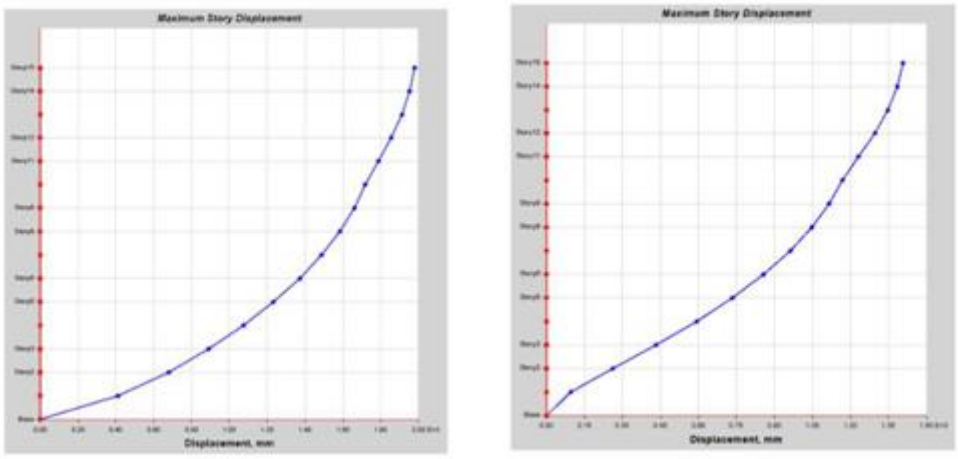

Fig. 13. Storey displacement due to EQ with and without base isolation for model no 1505100204

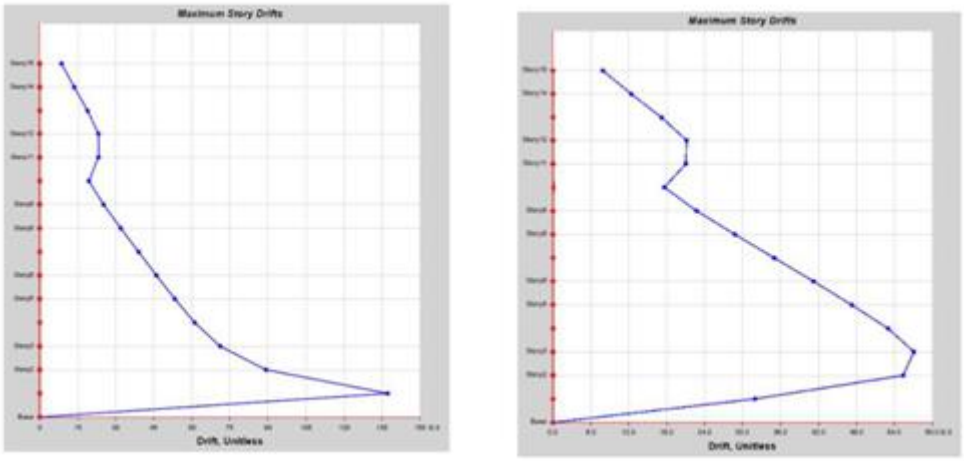

Fig. 14. Maximum Storey Drift due to EQ with and without base isolation for model no 1505100204

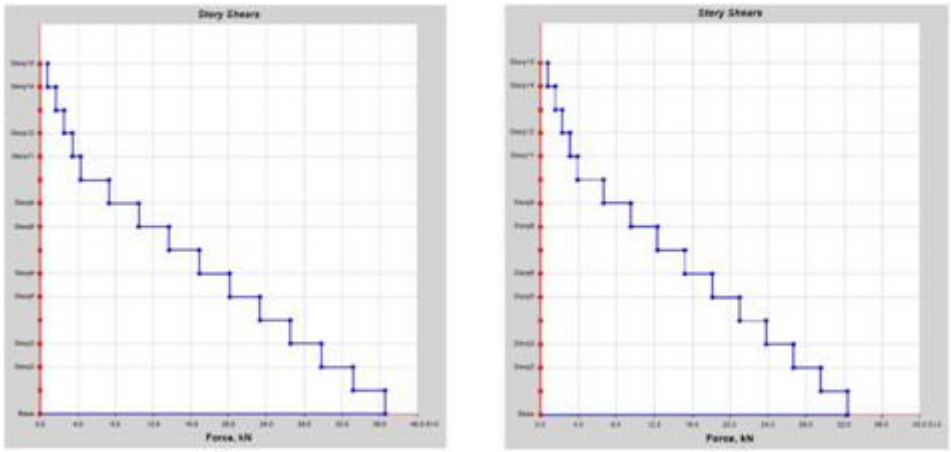

Fig. 15. Storey Shear due to EQ with and without base isolation for model no 1505100204

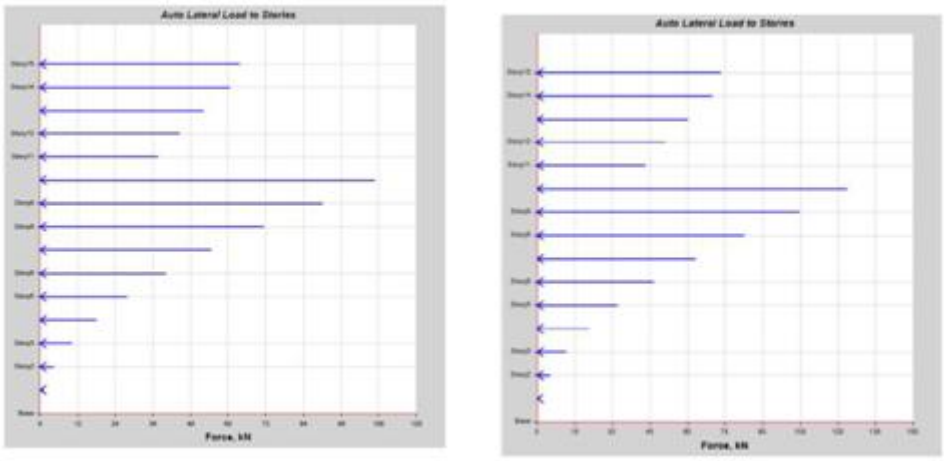

Fig. 16. Lateral Load due to EQx with and without base isolation for model no 1505100204

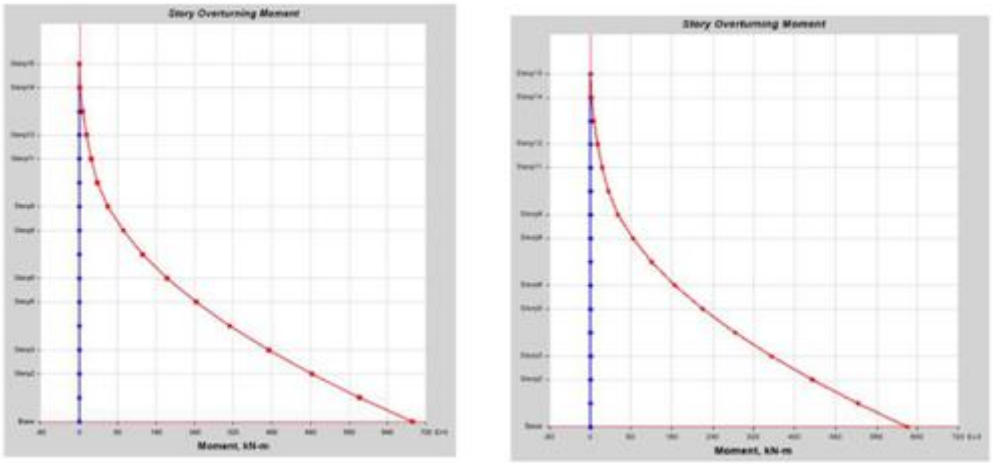

Fig. 17. Overturning Moment due to EQ with and without base isolation for model no 1505100204

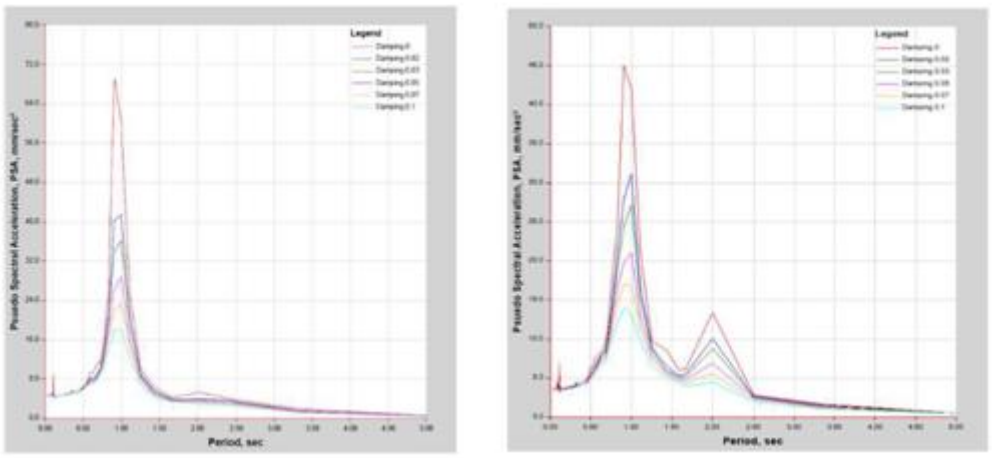

Fig. 18. Response Spectrum Curve with and without base isolation for model no 1505100204

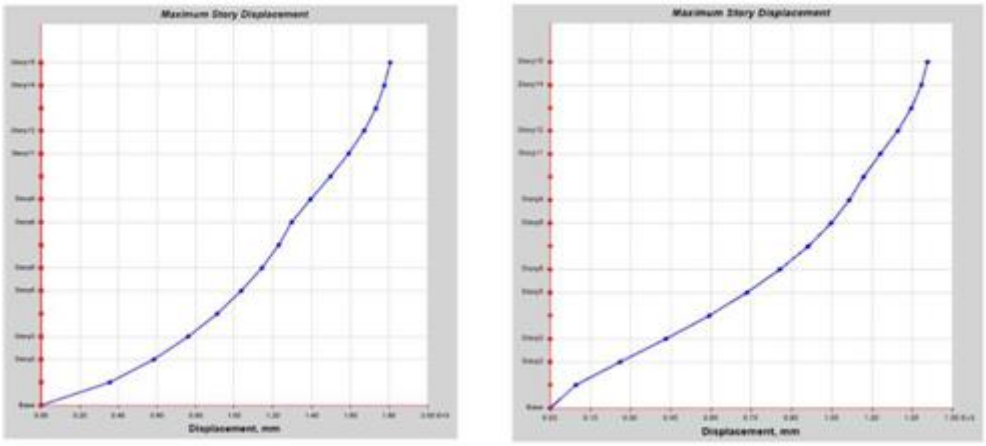

Fig. 19. Storey displacement due to EQ with and without base isolation for model no 1507080204

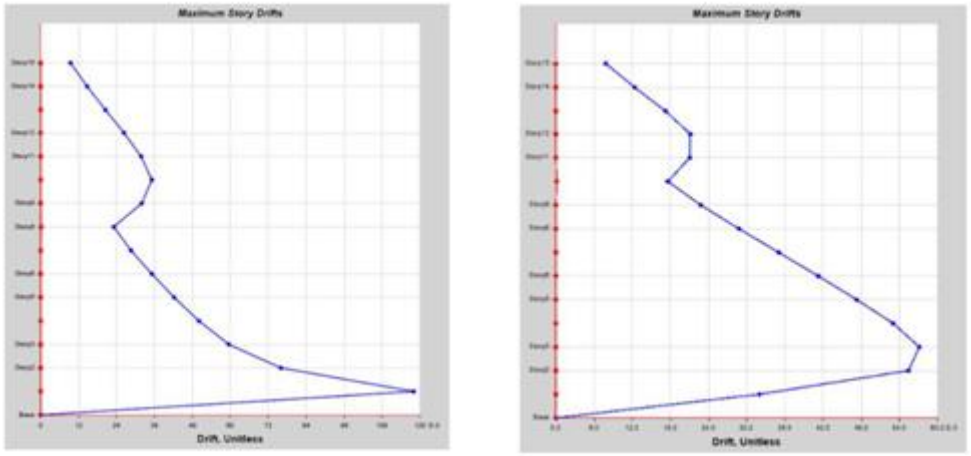

Fig. 20. Maximum Storey Drift due to EQ with and without base isolation for model no 1507080204

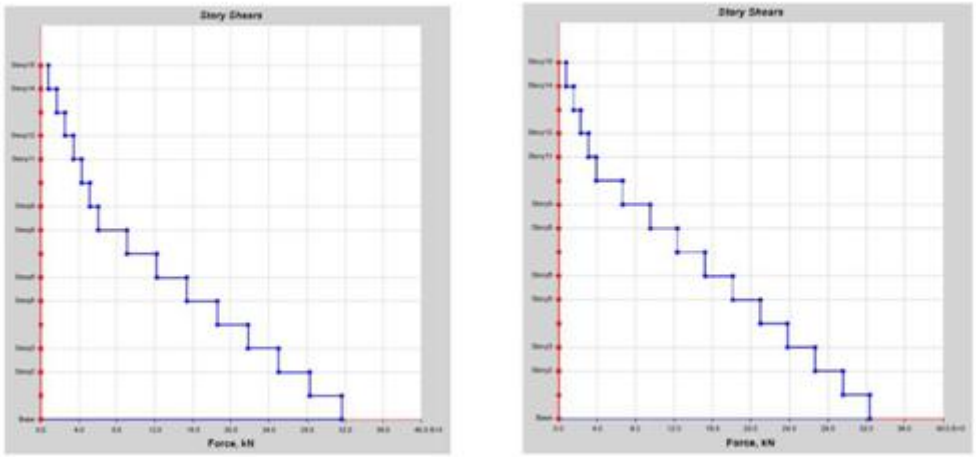

Fig. 21. Storey Shear due to EQ with and without base isolation for model no 1507080204

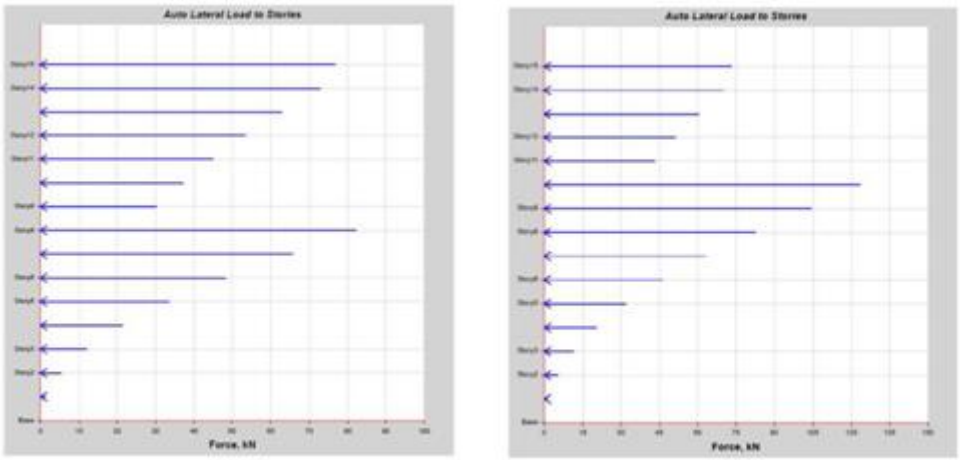

Fig. 22. Lateral Load due to EQx with and without base isolation for model no 1507080204

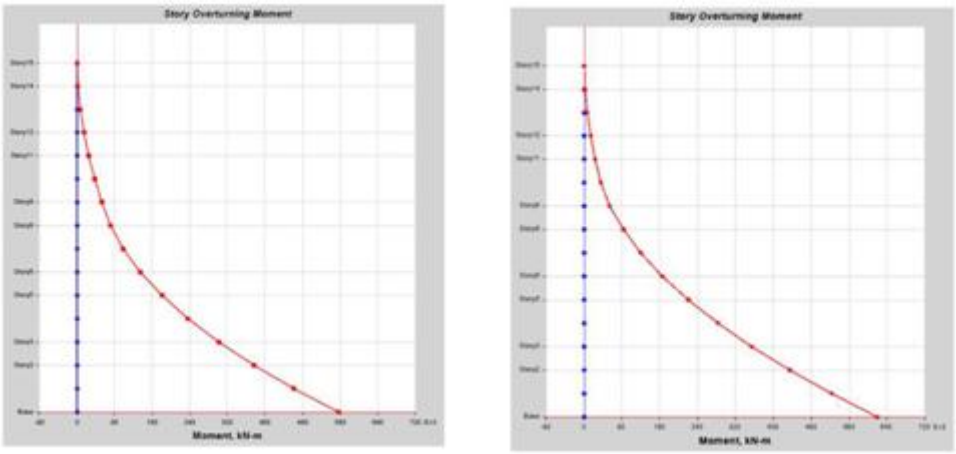

Fig. 23. Overturning Moment due to EQ with and without base isolation for model no 1507080204

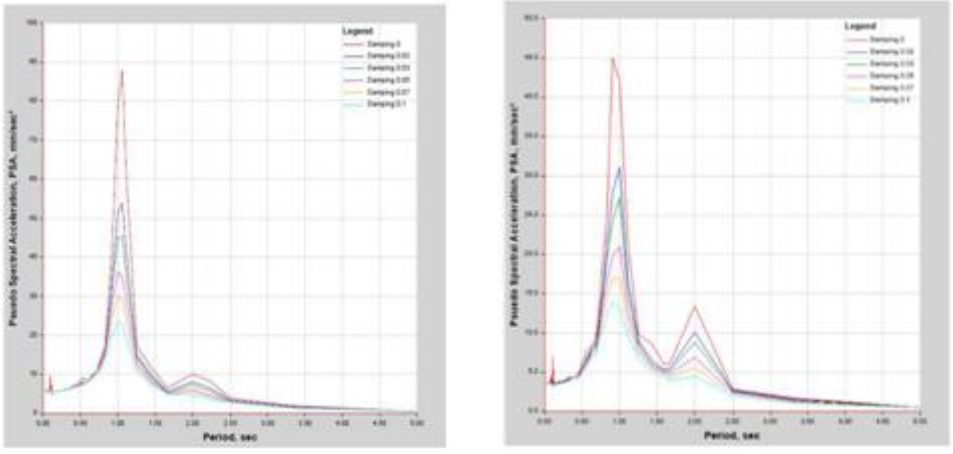

Fig. 24. Response Spectrum Curve due to EQ with and without base isolation for model no 1507080204

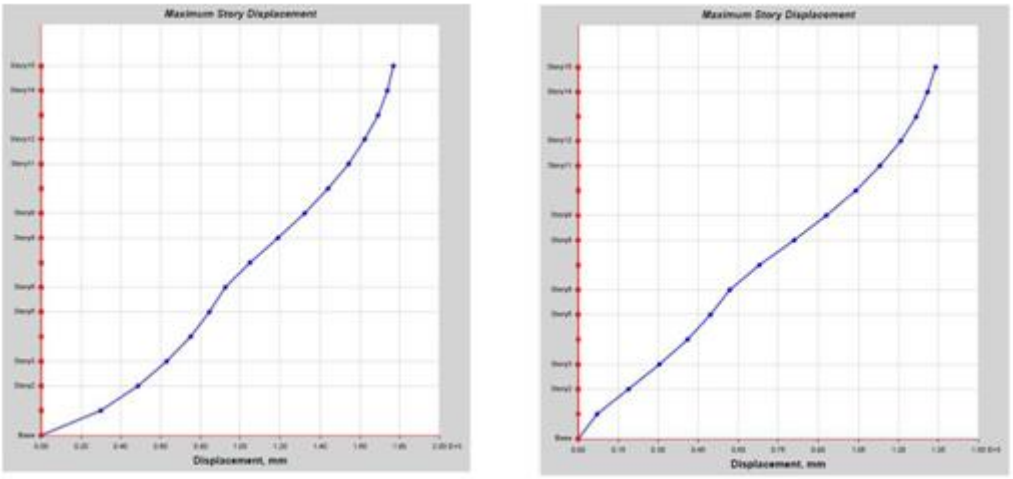

Fig. 25. Storey displacement due to EQ with and without base isolation for model no 1509060204

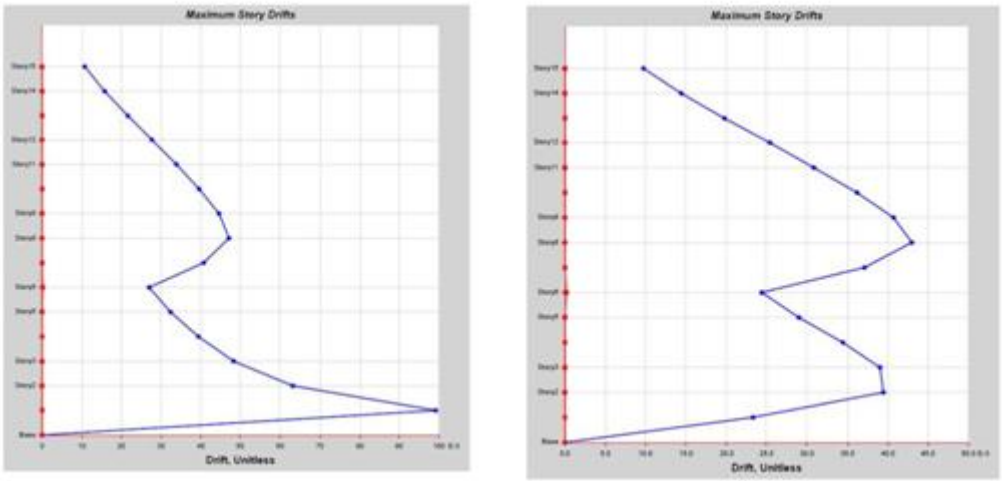

Fig. 26. Maximum Storey Drift due to EQ with and without base isolation for model no 1509060204

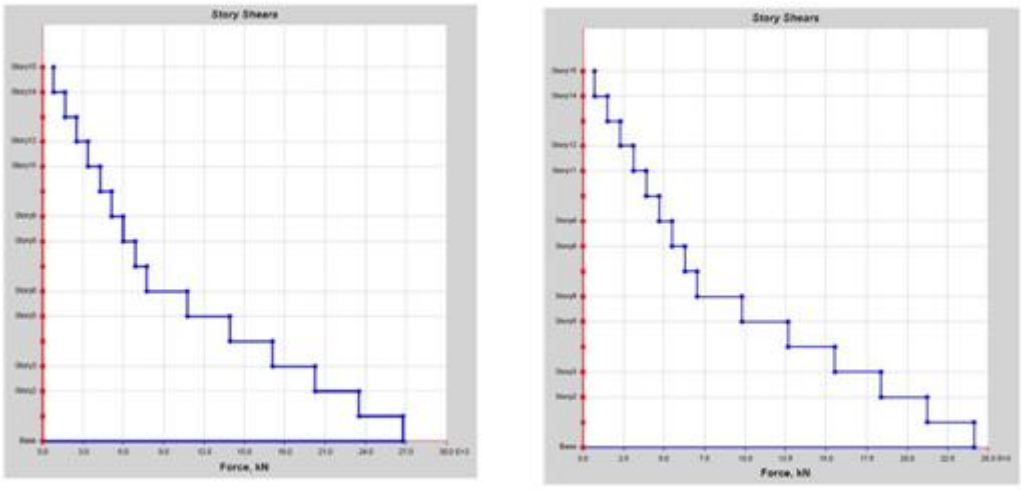

Fig. 27. Storey Shear due to EQ with and without base isolation for model no 1509060204

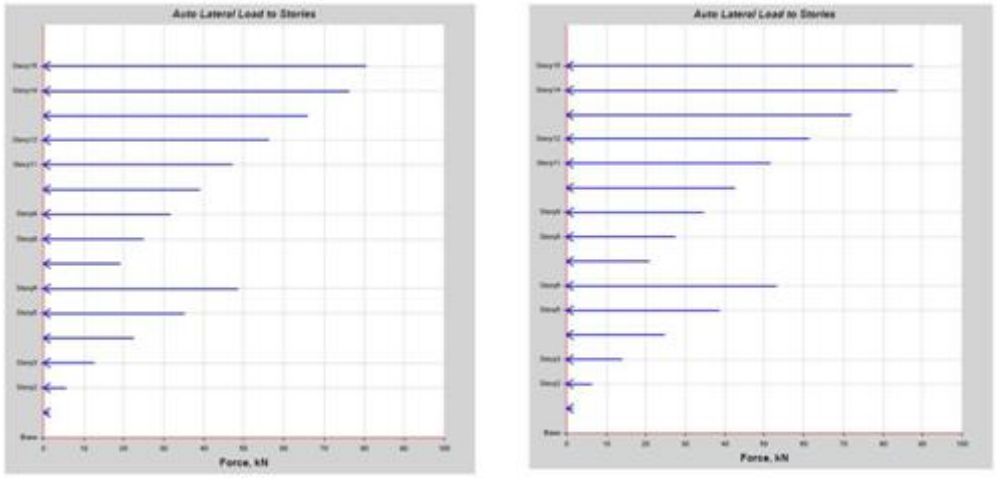

Fig. 28. Lateral Load due to EQx with and without base isolation for model no 1509060204

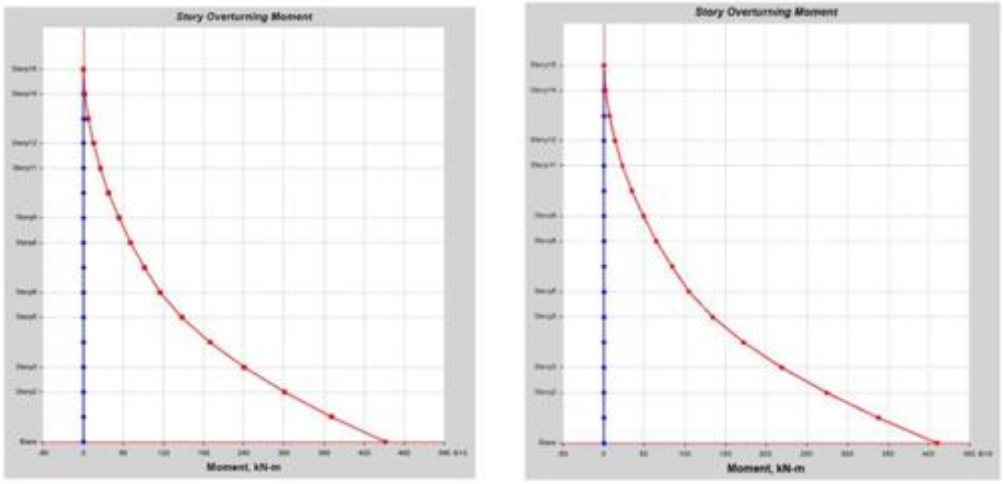

Fig. 29. Overturning Moment due to EQ with and without base isolation for model no 1509060204

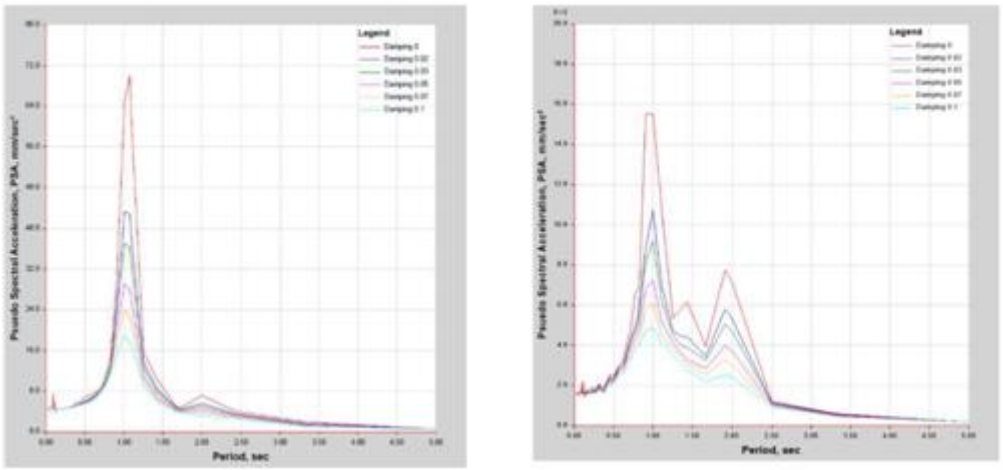

Fig. 30. Response Spectrum Curve with and without base isolation for model no 150906020

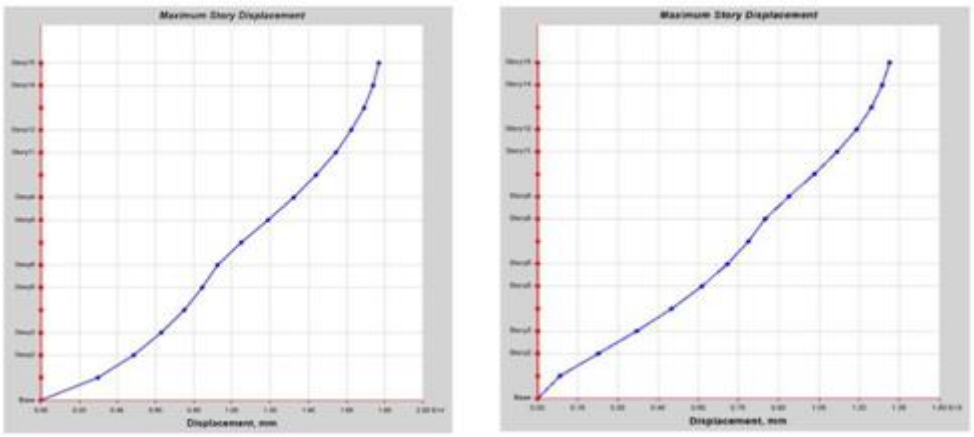

Fig. 31. Storey displacement due to EQ with and without base isolation for model no 1511040204

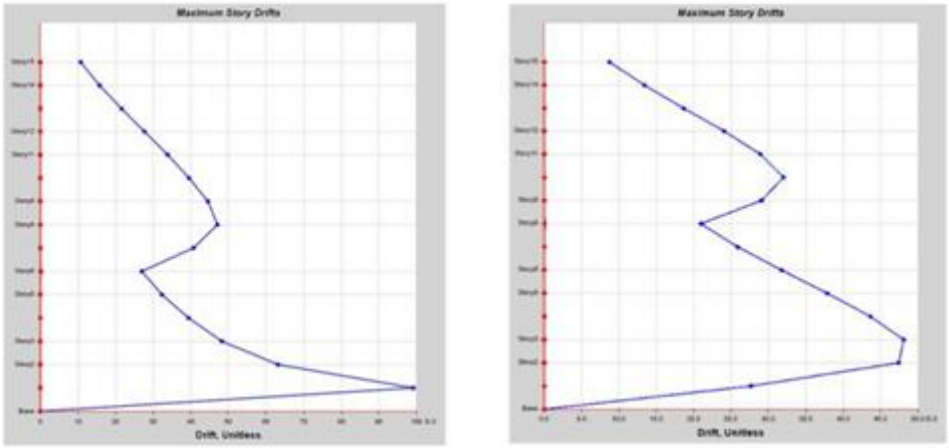

Fig. 32. Maximum Storey Drift due to EQ with and without base isolation for model no 1511040204

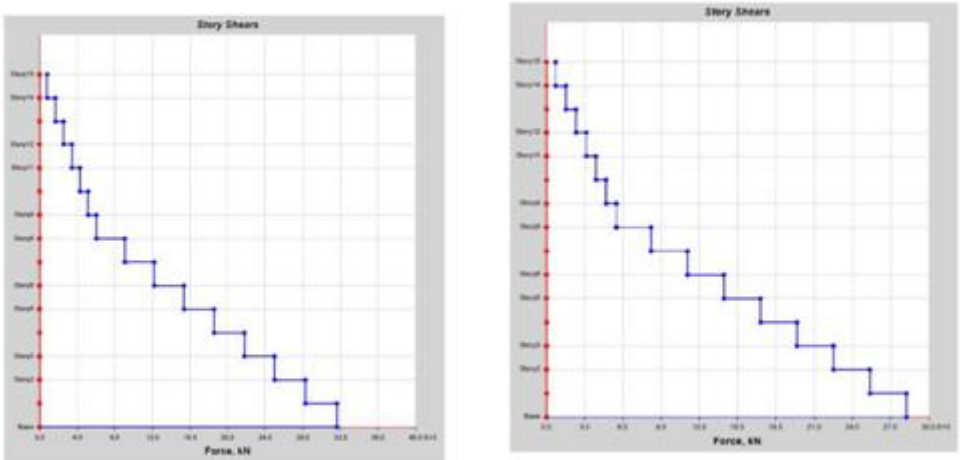

Fig. 33. Storey Shear due to EQ with and without base isolation for model no 1511040204

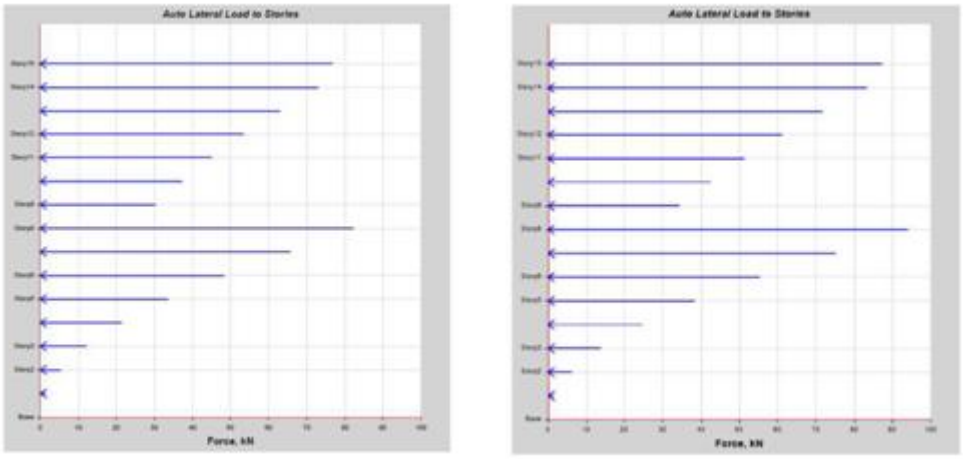

Fig. 34. Lateral Load due to EQx with and without base isolation for model no 1511040204

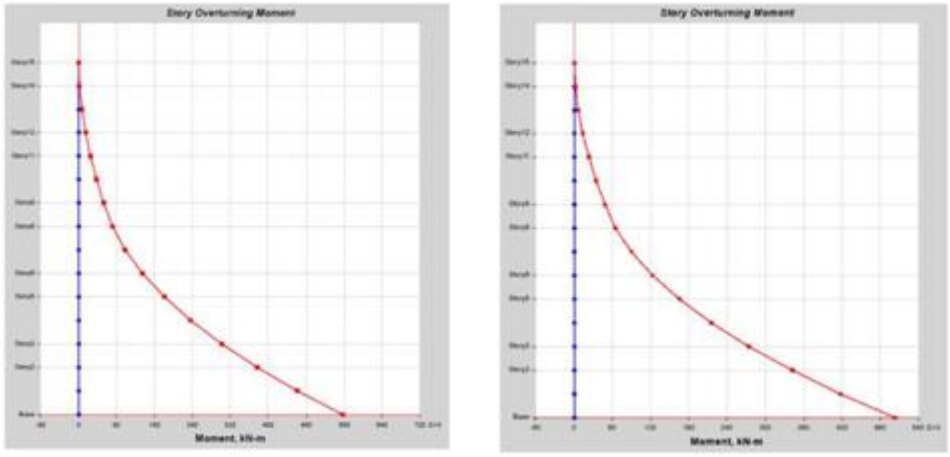

Fig. 35. Overturning Moment due to EQ with and without base isolation for model no 1511040204

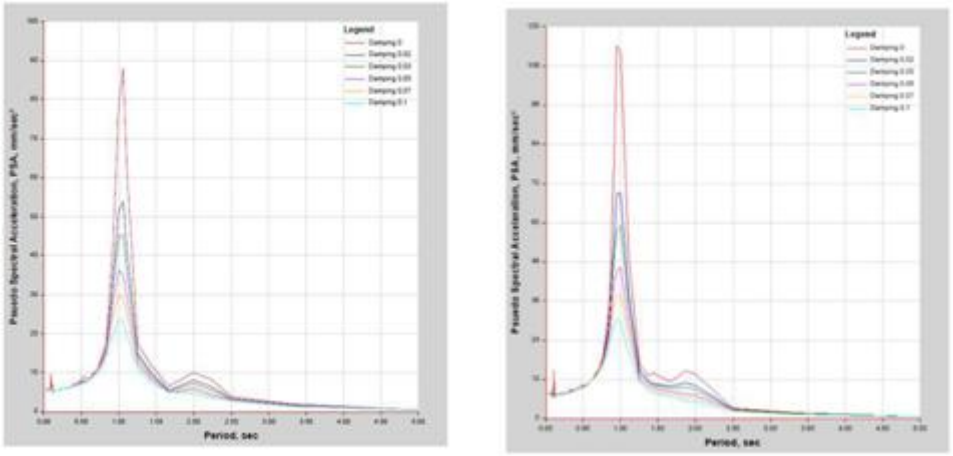

Fig. 36. Response Spectrum Curve with and without base isolation for model no 1511040204

9. Results and Conclusion

Unlike other seismic force reduction techniques, base isolators work to disconnect the structure from the source of the force itself rather than reducing the effect of existing seismic activity.

With ETABS 2016 software, a fifteen-story high-rise subjected to wind, seismic, and live loads were analyzed. With the use of graphs and lateral displacements given in Fig 14 to Fig 36, the behavior of high-rise buildings was readily displayed.

The base isolation system is an extraordinary and widely recognized advancement that is used to save innumerable lives and money spent on destruction caused by earthquakes. Modal frequency values are much closer for both models in both conditions given by SAP2000 and the horizontal shake table. When base isolators are present in the models (Ref Fig.6, Fig.8, Fig.10 and Fig.12), the modal frequency values are lower, and the values are greater in the frame when they are missing. These findings demonstrate how the base-isolated model greatly reduces or absorbs ground movements.

When comparing the results of the examination of buildings that are not isolated from one another, one may observe the effectiveness of isolation technology. Due to a reduction in the amount of lateral loads experienced by the structure, the acceleration imparted to the various stories also decreases. In the base-isolated building, storey shear and storey overturning moment are likewise decreased, which makes the superstructure above the isolation plane more robust and stiffer. The base-isolated structure proved to be more secure and safer than a structure with more than ten stories, according to research conducted using the base isolation technology at the (G+15) story building. An increase in maximum storey displacement was observed since the Base Isolators reduce the seismic effect by allowing free motion of the structure in two axes.

Mitigating the Effects of Earthquake

Mitigating the effects of earthquakes involves various strategies and technologies aimed at enhancing the earthquake resistance of buildings and infrastructure. Some key approaches are given below:

Seismic Design Codes

Building Codes: Implementing and strictly enforcing modern building codes that require earthquake-resistant designs, considering local seismic risks.

Performance-based Design: Designing buildings to meet specific performance objectives during an earthquake, such as preventing collapse or minimizing damage.

Structural Reinforcement

Base Isolation: Installing base isolators that decouple the building from ground motion, allowing the building to move independently of the earthquake's vibrations.

Dampers: Incorporating dampers (e.g., tuned mass dampers, viscous dampers) to absorb and dissipate seismic energy, reducing the building's motion.

Shear Walls: Adding shear walls to increase the building's lateral stiffness and strength, helping to resist horizontal forces.

Bracing: Using diagonal braces (e.g., steel braces, X-bracing) to provide additional lateral support and distribute seismic forces.

Retrofitting Existing Buildings

Strengthening Foundations: Enhancing the foundation to better anchor the building and prevent settlement or sliding.

Reinforcing Walls and Floors: Adding steel plates, fiber-reinforced polymers, or concrete overlays to strengthen existing walls and floors.

Seismic Joints: Introducing expansion joints to allow different sections of a building to move independently during an earthquake, reducing overall stress.

Materials and Construction Techniques

Flexible Materials: Use materials that can bend or flex without breaking, such as certain types of steel and reinforced concrete.

Quality Control: Ensuring high-quality construction practices and materials to prevent structural weaknesses.

Credit Authorship Contribution Statement

- Amitava Sil – Writing, review and

editing, supervision, original draft, conceptualization, resources & management

- Sourav Dandapat - Writing – Original Draft, Editing, Visualization, Software, Data Creation, Investigation Conceptualization
- Rishav Raj - Writing – Original Draft, Editing, Visualization, Software, Formal Analysis, Data Creation & Methodology

Declaration of Competing Interest

The authors state that they have no known conflicting financial interests or personal ties that might have influenced the work presented in this study.

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