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EVALUATION OF SEISMIC DEMANDS IN SYMMETRICAL AND ASYMMETRICAL RCC BUILDINGS WITH RUBER BASE ISOLATOR

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Abstract: This study evaluates seismic demands in symmetrical and asymmetrical reinforced concrete (RCC) buildings equipped with rubber base isolators. Using Non-Linear Time History Analysis (NLTHA), the research examines eight building models representing various configurations: four building heights (G+5, G+10, G+15, and G+20 stories) with both regular rectangular and irregular L-shaped floor plans, each analyzed with conventional fixed foundations and base isolation systems. The investigation utilizes ETABS 2020 software and "Bhuj" earthquake ground motion data to assess building performance in seismic zone IV. Results demonstrate that base isolators significantly reduce story drifts, with effectiveness varying by building height and symmetry - achieving an 8.23% reduction in symmetric five-story buildings compared to 83.75% in twenty-story structures. The isolators also substantially decrease base shear and torsional effects across all configurations. The findings indicate that rubber base isolators provide effective earthquake protection for both low-rise and high-rise buildings, with particularly strong performance in taller structures. This research supports wider implementation of base isolation technology in seismic regions, especially in India's zones 4 and 5, where they offer a cost- effective solution for reducing earthquake damage while minimizing post-event maintenance requirements.

Key Words: Rubber bearing base isolation, High rise building, nonlinear time history.

Introduction

A natural earthquake occurs when sudden movements or shaking take place within the Earth's crust due to tectonic stress. Shock waves from nuclear blasts and bombs are not classified as natural earthquakes. The Earth's structure consists of plates, and their junctions, called faults, experience stress that leads to earthquakes. Unlike buildings that can collapse, earthquakes only cause structural damage. Engineers use advanced computer technology to simulate building performance during earthquakes, improving safety and efficiency. Over the years, technology has reduced the labor and time needed for structural analysis. Building regulations ensure structures can withstand specific ground acceleration levels based on seismic risk. Earthquake- resistant designs focus on flexibility rather than rigid, heavy constructions. Limit state techniques have revolutionized construction, making buildings safer, faster to build, and cost-effective. Engineers must balance seismic performance, safety, and construction restrictions using innovative approaches. Non-Linear Time History analysis is the most reliable method for evaluating earthquake resilience. Since earthquakes are unpredictable, new analytical methods are needed to improve structural safety. International frameworks exist to regulate earthquake- resistant construction and evolve with new developments. Factors like lateral strength, ductility, and structural configuration influence building behavior. As urbanization grows, earthquake engineering plays a crucial role in ensuring safety and sustainability.

Objectives of the study

This study has objectives as:

- To study the seismic requirements of several regular and irregular RC structures using NLTHA
- Demonstrate impact of base isolators on symmetric and asymmetric buildings ranging from low-rise to high-rise.
- The self-motivated structural response to loads, which may vary over a certain time function, is evaluated using time-history analysis.

Literature Review

Anil Ninawe, Sanket Sanghai, 2024[1] in this paper, Base isolation is a seismic protection technique that decouples a building from ground motion, thereby reducing seismic forces transmitted to the structure. **Pranit Rajput et al., 2023 [2]** in this paper, Seismic performance analysis is critical in structural engineering, especially in earthquake-prone areas. **Yazıcıoğlu, Eylem Bilge, 2022 [3]** in this paper, The seismic response of reinforced concrete (RC) buildings is significantly influenced by their geometrical and material properties, particularly in the presence of horizontal irregularities and the implementation of base isolation systems. **Yan Xiao et al., 2020 [4]** in this paper, they utilize advanced numerical simulations to analyze the seismic performance of buildings equipped with LRBs under various earthquake loading conditions. **Vahid Barzegar**, **Simon Laflamme 2019 [5]** in this paper, this study investigates a novel passive variable friction damper (PVFD) designed to mitigate vibrations induced by seismic activity. **S.M. Wilkinson et al., 2019 [6]** in this paper, Multi-story buildings in seismic zone IV, both with and without outrigger systems, are the subject of a parametric analysis. **Fabio Mazza and Mirko Mazza 2018 [7]** in this, they investigated the combined performance of RC-bracing and shear walls, as well as the impact of their relative positions in high-rise buildings (G+10). **S. M. Kalantari et al., 2018 [8]** ETABS to analyze a (G+15)-storey building frame in seismic zone-II. The displacements seen in the model with and without a shear wall at various points were compared. **Mohit Kumar Prajapati et al., 2017 [9]** they carried out a comprehensive investigation to identify the best location of a shear wall in a multi-storey building, based on elasto-plastic and elastic properties. **S. Gyawali et al., 2017 [10]** The G+10 high steel skyscraper with the X bracing system is the subject of the response structural analysis. This paper uses Etabs for analysis. Peak storey, mode form, natural frequency, and fundamental time period are computed. **Hamidreza Baghaei, Reza Razani 2017 [11]**, this paper emphasizes a novel idea for stopping a residential building's lateral displacement by optimally strengthening the top or intermediate storey.

Research Methodology

The Non-Linear Time History Analysis (NLTHA) performs dynamic inelastic analysis to determine earthquake demands on structures. It compares performance with base-isolated buildings using tuned mass dampers for better earthquake resistance. The evaluation includes global and inter-storey displacements, elastic deformations, and connection forces. Structural seismic response and deformation requirements are estimated through inelastic deformation time records. NLTHA accurately simulates building responses to seismic forces, requiring multiple studies and 3D analytical models for precise assessments. Current analytical tools remain limited or difficult to use. NLTHA follows international seismic analysis standards like ATC-40 and FEMA 273/356, shifting from traditional linear and static methods. Older buildings used brittle, heavy materials, increasing construction costs. The introduction of limit state design reduced costs, improved flexibility, and accelerated construction. Seismic energy dissipation techniques allow engineers to enhance performance evaluation and monitoring. Mathematical models help designers predict structural responses under load conditions. Commercial software can assist with structural modeling, analysis, and design. Engineers must forecast how buildings react to different loads at set assurance levels. NLTHA is the most effective method for precise structural integrity testing under seismic stress. Experts and codes widely recognize NLTHA as the most reliable approach for seismic assessment.

Non-Linear Time History Analysis (Nltha)

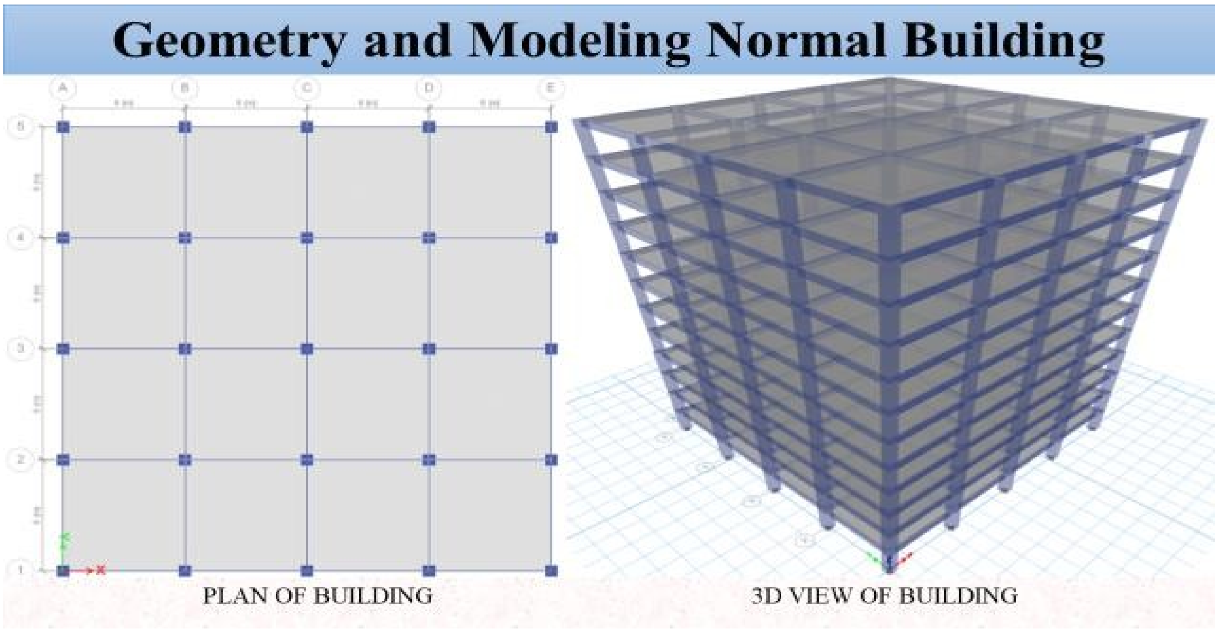
Time History Analysis (THA) evaluates structural response over multiple time steps, incorporating initial conditions and the full loading sequence. It systematically adjusts structural properties, like stiffness, to capture non-linear behavior. This method is the most effective for predicting seismic force and deformation needs, as it calculates internal force redistribution beyond elastic limits. Unlike linear analysis, THA provides precise response data, though accuracy and load path validation remain challenges. It assesses all structural and non-structural components, including joints and foundations. Proper integration of inelastic properties in 3D models enhances its effectiveness. NLTHA, governed by ATC-40 and FEMA standards, calculates responses at multiple time steps, capturing inelastic deformation during earthquake loading.

Model Description

This study analyzes the seismic response of a building under earthquake loading using ETABS 2020. The building plan features an asymmetrical layout along both the X and Y axes, with bays measuring 6 meters each. Two reinforced concrete ordinary moment-resisting frame structures, one with 30 storeys and the other with 50 storeys, are considered, both having identical loads, characteristics, columns, and tube-in-tube systems at the center and periphery. A non-linear dynamic analysis was performed on these structures, each with an average storey height of 3 meters. The "Bhuj" earthquake ground motion data was used for this non-linear time history analysis. A total of eight models were studied in seismic zone IV.

Model 1 – G+5 Normal Building with and without base isolation (normal shape)
Model 2 – G+10 Normal Building with and without base isolation (normal shape)
Model 3 – G+15 Normal Building with and without base isolation (normal shape)
Model 4 – G+20 Normal Building with and without base isolation (normal shape)
Model 5 – G+5 Normal Building with and without base isolation (L shape)

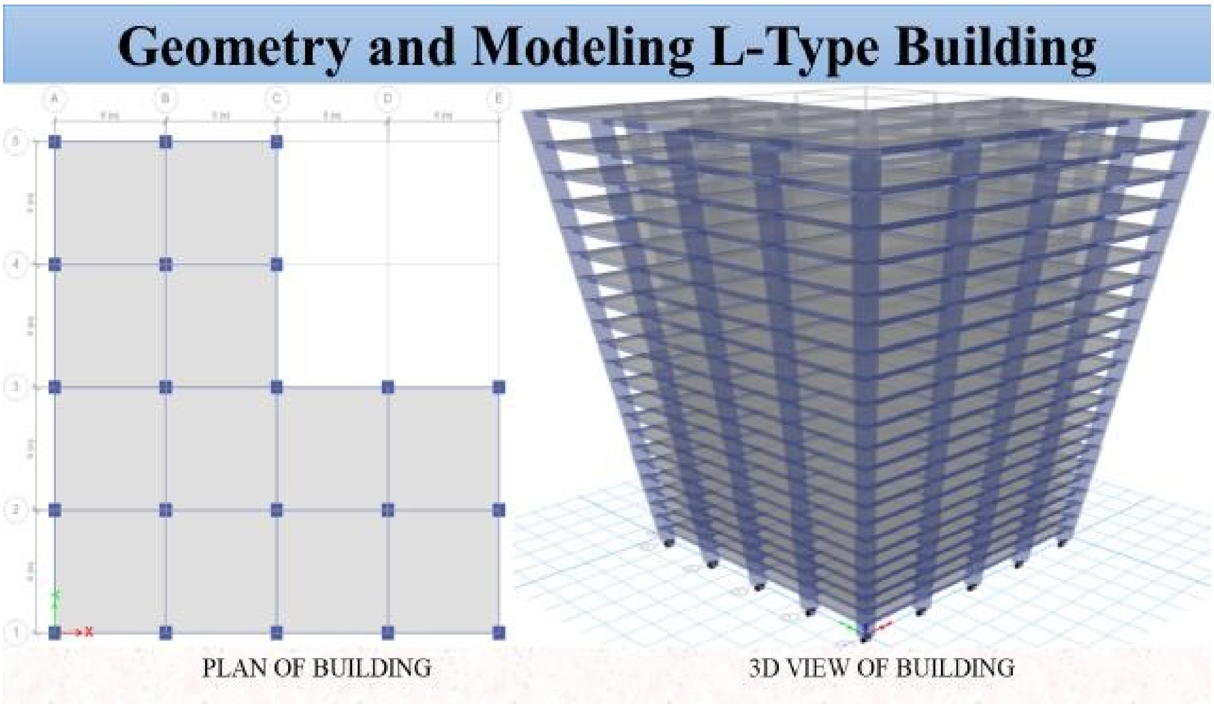
Model 6 – G+10 Normal Building with and without base isolation (L shape)
Model 7 – G+15 Normal Building with and without base isolation (L shape)
Model 8 – G+20 Normal Building with and without base isolation (L shape)



Geometry and Modeling Normal Building

PLAN OF BUILDING

3D VIEW OF BUILDING



Geometry and Modeling L-Type Building

PLAN OF BUILDING

3D VIEW OF BUILDING

Interpretation

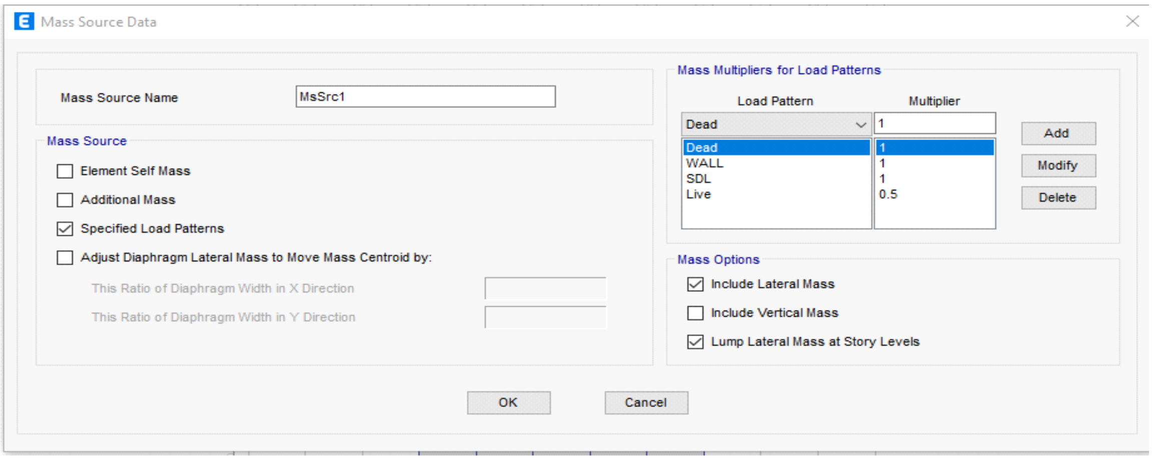
This structural engineering study examines the effectiveness of base isolation systems across eight building configurations, varying three key parameters: building height (G+5, G+10, G+15, and G+20 stories), floor plan geometry (regular rectangular shape versus irregular L-shape), and foundation type (conventional fixed base versus base-isolated). The comprehensive analysis likely aims to quantify how base isolation performance changes with increasing building height and irregular geometry, measuring improvements in seismic response metrics such as story drift, acceleration, and base shear reduction compared to conventional foundations - ultimately providing design guidance for implementing base isolation across diverse building typologies.

Analysis methods

Material nonlinearity & geometric nonlinearity may be integrated into the study to enhance the outcomes. Structures' strength, deformation, ductility, and distribution of demands can be assessed using these methods.

Equivalent static method

This is linear static method of analysis, in which the response of the building is assumed to be linearly elastic. Therefore, the equivalent static method of analysis follows a linear analysis procedure as well. In accordance with IS1893-2016, the analysis was carried out.



Mass Source Data

Mass Source Name: MsSrc1

Mass Source

☐ Element Self Mass
☐ Additional Mass
☑ Specified Load Patterns
☐ Adjust Diaphragm Lateral Mass to Move Mass Centroid by:
This Ratio of Diaphragm Width in X Direction
This Ratio of Diaphragm Width in Y Direction

Mass Multipliers for Load Patterns

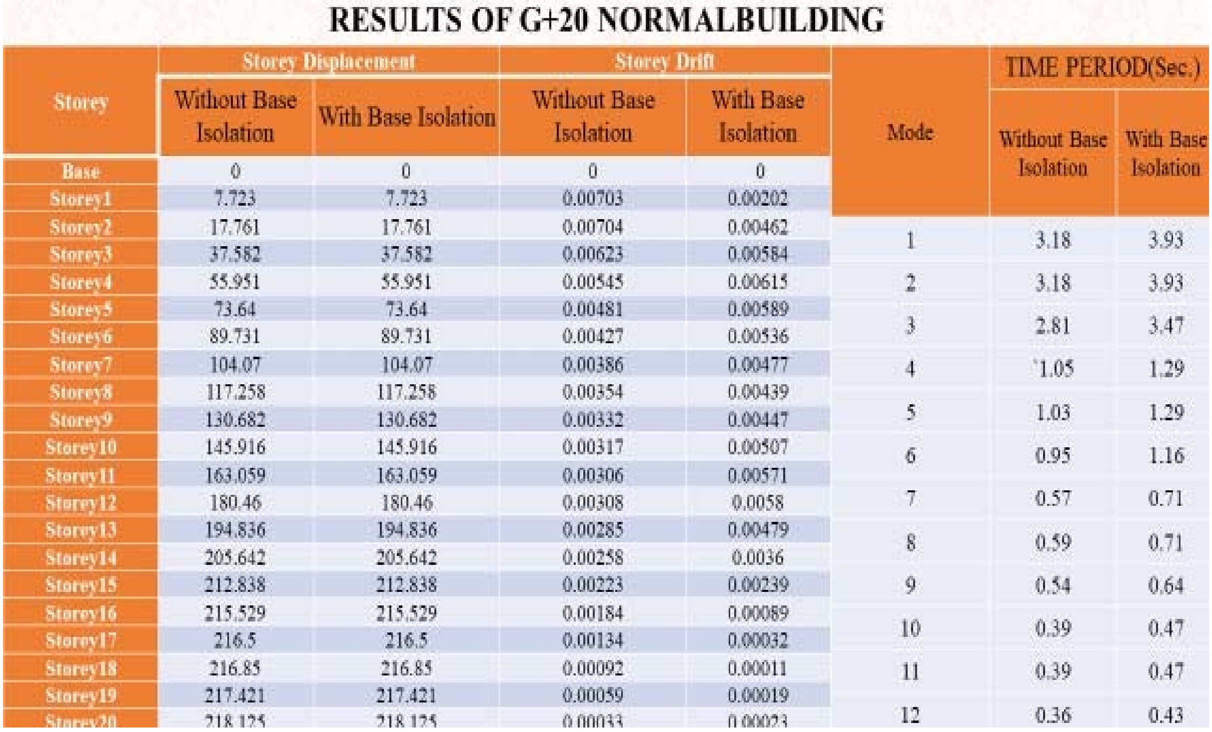
Load Pattern	Multiplier
Dead	1
Dead	1
WALL	1
SDL	1
Live	0.5

Mass Options

☑ Include Lateral Mass
☐ Include Vertical Mass
☑ Lump Lateral Mass at Story Levels

Results and Discussions

Torsion, modal periods, base shear, and story drifts were analyzed as key variables to obtain the results. This paper presents Time History analysis findings from Non-Linear Base Isolation techniques applied to five-storey and twenty-storey symmetric and asymmetric buildings. The dissertation provides data on the impact of base isolation on base shear, torsion, and structural response, specifically in terms of storey drifts, for both symmetric and asymmetric structures.

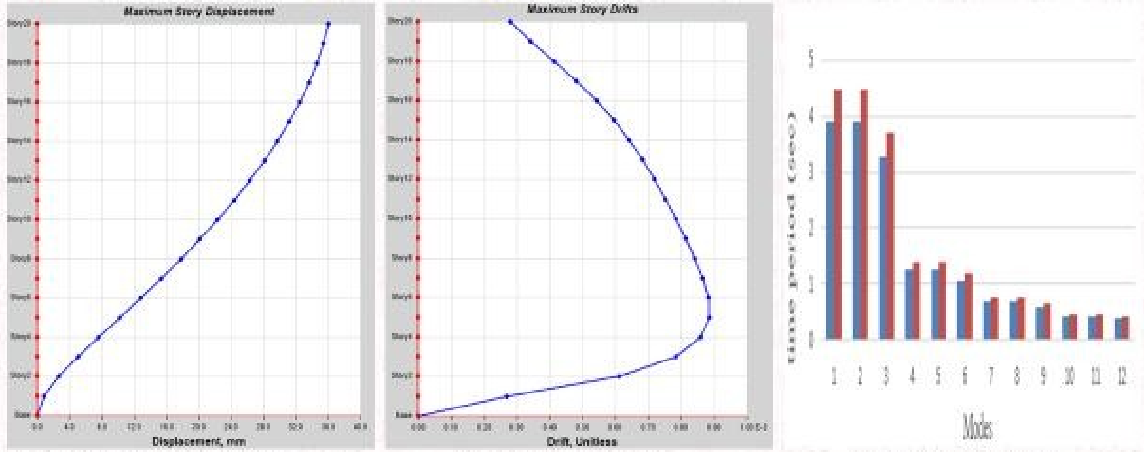


RESULTS OF G+20 NORMALBUILDING

Storey	Storey Displacement		Storey Drift	
	Without Base Isolation	With Base Isolation	Without Base Isolation	With Base Isolation
Base	0	0	0	0
Storey1	7.723	7.723	0.00703	0.00202
Storey2	17.761	17.761	0.00704	0.00462
Storey3	37.582	37.582	0.00623	0.00584
Storey4	55.951	55.951	0.00545	0.00615
Storey5	73.64	73.64	0.00481	0.00589
Storey6	89.731	89.731	0.00427	0.00536
Storey7	104.07	104.07	0.00386	0.00477
Storey8	117.258	117.258	0.00354	0.00439
Storey9	130.682	130.682	0.00332	0.00447
Storey10	145.916	145.916	0.00317	0.00507
Storey11	163.059	163.059	0.00306	0.00571
Storey12	180.46	180.46	0.00308	0.0058
Storey13	194.836	194.836	0.00285	0.00479
Storey14	205.642	205.642	0.00258	0.0036
Storey15	212.838	212.838	0.00223	0.00239
Storey16	215.529	215.529	0.00184	0.00089
Storey17	216.5	216.5	0.00134	0.00032
Storey18	216.85	216.85	0.00092	0.00011
Storey19	217.421	217.421	0.00059	0.00019
Storey20	218.125	218.125	0.00033	0.00023

Mode	TIME PERIOD(Sec.)	
	Without Base Isolation	With Base Isolation
1	3.18	3.93
2	3.18	3.93
3	2.81	3.47
4	'1.05	1.29
5	1.03	1.29
6	0.95	1.16
7	0.57	0.71
8	0.59	0.71
9	0.54	0.64
10	0.39	0.47
11	0.39	0.47
12	0.36	0.43

Graphical Representation of Storey displacement, Storey Drift and Time Period



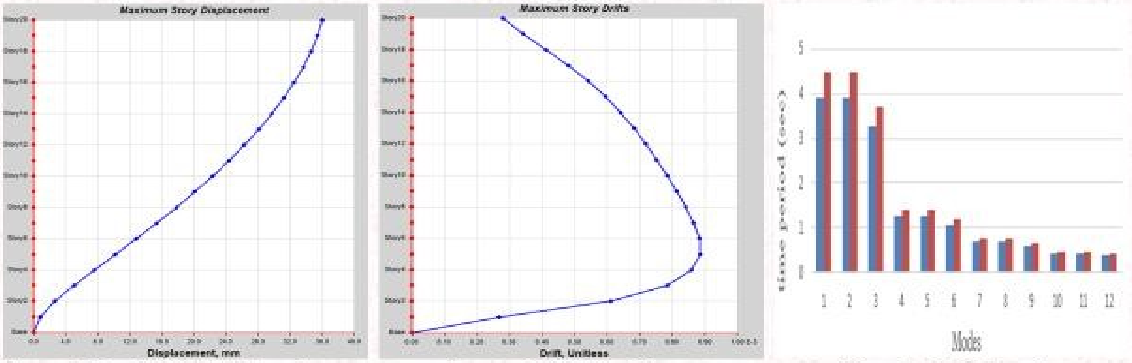
Storey Displacement Graph **Storey Drift Graph** **Time Period Graph**

RESULTS OF G+20 L-TYPE BUILDING

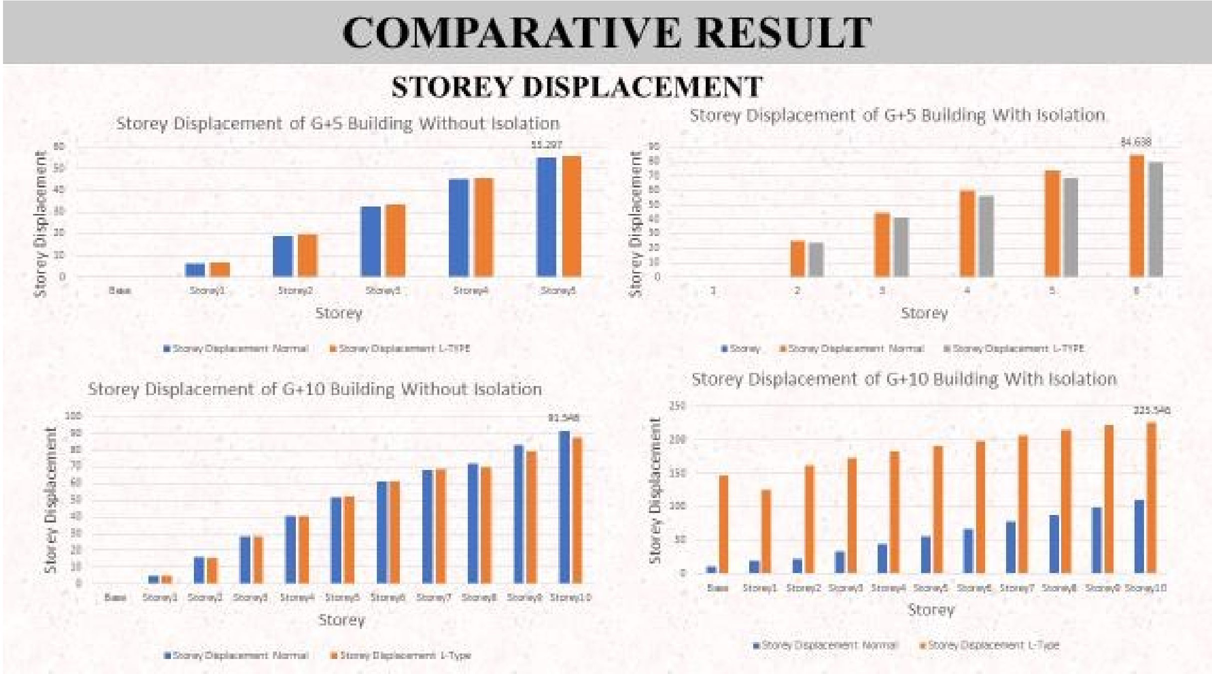
Storey	Storey Displacement		Storey Drift	
	Without Base Isolation	With Base Isolation	Without Base Isolation	With Base Isolation
Base	0	53.399	0.00762	0.00194
Storey1	5.836	76.245	0.00698	0.00447
Storey2	19.267	97.177	0.00618	0.00566
Storey3	36.277	115.713	0.00547	0.00599
Storey4	54.248	132.117	0.00486	0.00575
Storey5	71.518	146.706	0.00436	0.00524
Storey6	87.254	159.796	0.00396	0.00470
Storey7	101.373	171.681	0.00366	0.00442
Storey8	114.639	182.669	0.00346	0.00465
Storey9	128.597	193.056	0.00331	0.00542
Storey10	144.854	202.997	0.00321	0.00606
Storey11	163.051	212.621	0.00322	0.00609
Storey12	181.333	222.277	0.00312	0.00501
Storey13	196.367	231.283	0.00271	0.00371
Storey14	207.503	239.409	0.00237	0.00241
Storey15	214.734	246.506	0.00194	0.00051
Storey16	216.268	252.311	0.00147	0.00021
Storey17	216.917	256.733	0.00106	0.00039
Storey18	218.094	259.912	0.00069	0.00011

Mode	TIME PERIOD(Sec.)	
	Without Base Isolation	With Base Isolation
1		3.92
2	3.18	3.92
3	2.82	3.45
4	1.05	1.29
5	1.05	1.28
6	0.94	1.15
7	0.56	0.68
8	0.56	0.68
9	0.54	0.64
10	0.37	0.46
11	0.37	0.46
12	0.34	0.41

Graphical Representation of Storey displacement, Storey Drift and Time Period

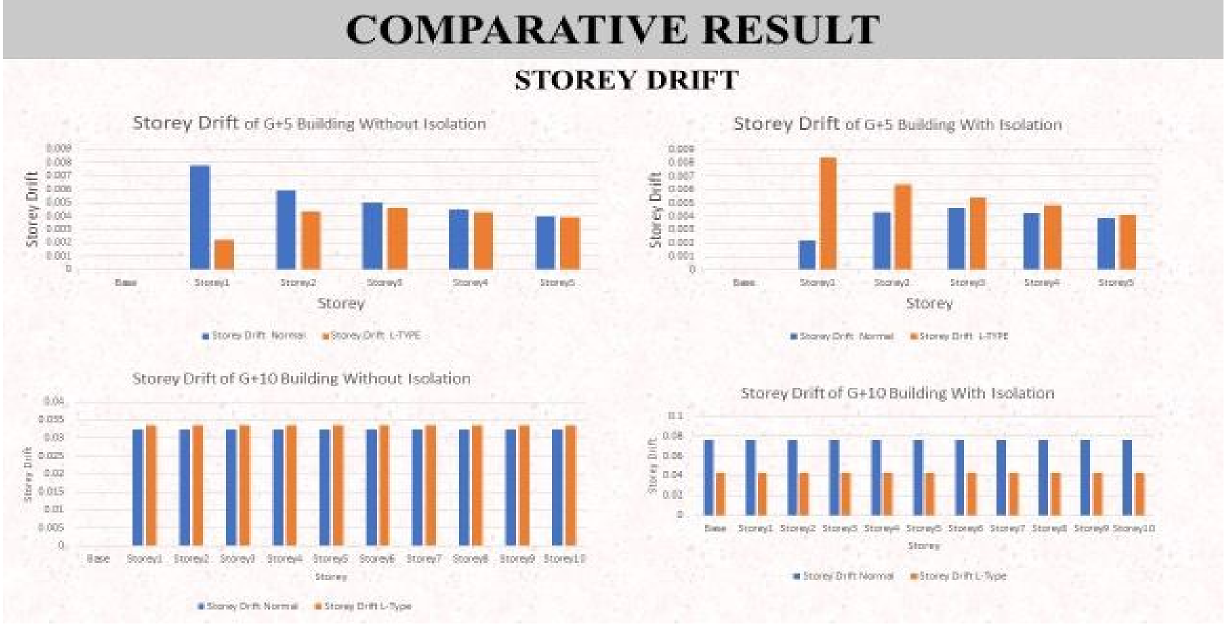


Storey Displacement Graph **Storey Drift Graph** **Time Period Graph**



COMPARATIVE RESULT

STOREY DISPLACEMENT



COMPARATIVE RESULT

STOREY DRIFT

Limitations

Following are limitations of present study

- The buildings which were modeled were regular and irregularly shaped having a constant area for 5, 10, 15, & 20 models.
- Plan Irregularities were considered in this dissertation.
- The structure was studied for lateral seismic loading.

Scope for further study

There are a growing number of scholars interested in the NLTHA, which means that field of study may expand significantly. Many scientists have found soil-structure interactions to be an intriguing issue for static techniques, with these interactions providing a comparable approach to non-linear time history analysis. The investigation of structural response to rotational loading necessitates conducting time history analysis with non-linear characteristics specifically under base rotation loading conditions. Base isolation systems would function more effectively when integrated with energy dissipation systems that incorporate tuned mass dampers and viscoelastic dampers, creating comprehensive protection mechanisms. Furthermore, base isolation systems require technological advancement to develop adaptive capabilities that allow their stiffness to automatically modify based on seismic intensity, enabling more responsive performance during varying earthquake conditions and optimizing structural protection across different magnitudes of seismic events.

Conclusion

1. In a symmetric five-storey structure, the storey drifts were reduced by 8.23%, while in an asymmetric five-storey building, they were reduced by 0.42%. Advocating the use of Base Isolators in Low-Rise Structures. The Storey Drifts for Twenty-storey Buildings were found to be reduced by 83.75% with symmetric buildings & with 55.71% for asymmetric buildings when the Isolation approach was used.
2. Base Isolators function as highly effective seismic control devices on five-storey buildings because they decrease base shear by 75% for symmetric buildings and decrease both base shear and base torsion moment by 75% and 78% respectively in asymmetric buildings.
3. Research findings demonstrated base isolators function as very effective seismic control devices for both symmetric and asymmetric structures of low- to high-rise heights.
4. The base isolation technique has been successfully used as an earthquake-resistant design strategy.
5. The extensive use of base isolators in seismically active hotspots indicates that India should adopt them during the approaching years. Base isolators need immediate promotion since they feature both high technical performance and low construction expenses particularly within zones 4 and 5. The use of foundation isolators lowers inter-story drift to reduce post-earthquake structural damage. Minor maintenance work will transform the facility into an inhabitable state.
6. Since lateral displacement at base is not equal to 0, base-isolated structures display less lateral deflection & fewer moment values than fixed base structure.

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