Study of the Seismic Behavior of Multistorey Building with and without Base Isolation and Liquid Tunned Mass Damper

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Abstract: **This study investigates the behavior of base isolation and liquid tuned mass dampers (LTMD) in enhancing the structural stability and mitigating dynamic loads in high-rise buildings. Base Isolation, utilizing flexible bearings, decouples the building from ground motion, effectively reducing seismic forces. LTMDs, comprising liquid-filled tanks, counteract wind-induced vibrations by oscillating in opposition to the building's movement. Utilizing ETABS software, dynamic analyses were conducted on a G+12 storey RCC structure under various scenarios, including seismic and blast loads. Results indicated significant reductions in displacement, story drift, and base shear when employing both base isolation and LTMDs. The findings indicate substantial reductions in displacement, story drift, and base shear when employing both base isolation and LTMDs. For instance, the displacement in UX direction was reduced from 66.287 mm in the basic model to 0.803 mm with TMD. These results demonstrate that integrating these techniques enhances the seismic and wind resilience of high-rise buildings, thereby improving occupant safety and structural integrity.**

Keywords: **Base isolation, Liquid tuned mass dampers (LTMD), High-rise buildings, ETABS software.**

I. INTRODUCTION

In high-rise buildings, ensuring structural stability and mitigating the effects of dynamic loads such as wind and seismic forces is crucial. Two commonly employed techniques for achieving this are base isolation and liquid tuned mass dampers (TMDs). These techniques play a significant role in enhancing the behavior of high-rise buildings by reducing the impact of vibrations and increasing their overall safety and comfort. Base isolation is a seismic protection strategy that involves separating the building's superstructure from its foundation using flexible bearing systems. The purpose of base isolation is to decouple the building from the ground, allowing it to move independently during an earthquake or other dynamic events. This isolation helps in dissipating and absorbing the energy generated by the ground motion, thereby reducing the transmission of seismic forces to the building. The flexible bearings used in base isolation systems typically consist of layers of rubber and steel, which provide both vertical and horizontal flexibility. This flexibility allows the building to sway and deform during seismic events, minimizing the impact on the structure and its occupants. Base isolation has proven to be highly effective in reducing structural damage and enhancing the overall seismic performance of high-rise buildings.

An explosion is the sudden release of energy that is accompanied by a loud blast and a blinding flash. Thermal radiation is one of the energy's discharged forms. (flash) and portion are connected as radially extending shock waves to the substrate (the ground) as base shock and the air as air-blast.

Liquid tuned mass dampers (LTMDs) are another technique used to mitigate the dynamic response of high-rise buildings. TMDs are typically employed to counteract the effects of wind-induced vibrations. These vibrations can lead to discomfort for occupants and potential damage to the structure. A TMD consists of a mass (often a liquid-filled tank) connected to the building's structure through a series of dampers. The mass is tuned to resonate at a frequency that matches the natural frequency of the building, effectively reducing the building's response to dynamic loads. When the building experiences wind-induced vibrations, the TMD oscillates in opposition to the building's motion, thereby absorbing and dissipating the energy. The use of TMDs significantly reduces the amplitude of vibrations and enhances the overall stability and comfort of high-rise buildings. Both base isolation and liquid tuned mass dampers offer distinct advantages in high-rise buildings. Base isolation provides excellent protection against seismic forces by isolating the building from the ground motion. It allows the building to move independently, minimizing structural damage and protecting occupants. On the other hand, liquid tuned mass dampers are specifically designed to mitigate wind-induced vibrations, providing comfort and stability in high-wind areas. By incorporating these techniques, high-rise buildings can achieve improved structural behavior, reduced structural damage, and enhanced occupant safety and comfort in both seismic and wind-prone regions.

II LITERATURE REVIEW

Budhi Ram Chaudhary (2019) examined seismic behavior in reinforced concrete (RC) buildings with fixed bases, base isolation, and damper systems. Base isolation, a passive control device, effectively mitigates ground motion impacts by inserting low horizontal stiffness elements. Comparative analysis shows base isolation increases base shear, time period, and stiffness, while reducing story displacement. Base isolation is optimal for low- to medium-rise buildings, while dampers are suited for high-rise structures.

Hosein Naderpour (2019) investigated the combined use of base isolation and non-traditional TMDs to reduce high-rise building seismic response. Analysis of multi-story structures exposed to various earthquakes revealed that while TMDs alone reduce response by up to 20%, base isolation alone can achieve over 70% reduction. The combined systems provided the highest reduction, exceeding 80%.

Chunxiang Li (2021**)** explores a nonlinear hybrid base isolation system combined with a tuned mass damper inerter (BIS-TMDI). Results from numerical analysis and genetic algorithm optimization show BIS-TMDI significantly reduces isolation layer displacement under strong earthquakes. The system's robustness outperforms traditional BIS-TMD systems, especially against near-fault ground motions.

ArcanYanik (2023) addresses base isolation with soil-structure interaction (SSI) under earthquakes. Dynamic simulations of various structures revealed that SSI can diminish base isolation effectiveness, especially in softer soils. Results indicate that incorporating SSI into mass, damping, and stiffness matrices of base-isolated structures is crucial for accurate seismic performance assessment.

HamidrezaAnajaf (2018) Proposing a partial mass isolation (PMI) technique, this study optimizes parameters to minimize inter-story drift responses under Gaussian white noise excitations. PMI's seismic performance was compared with TMD and base-isolation systems. The study found PMI, with mass ratios of 5%-90%, dynamically equivalent to TMD or ideal base-isolation systems, addressing limitations in high-rise buildings.

2.1 Research gap

Most studies focus on specific building heights and TMD configurations, lacking comprehensive analyses comparing multiple high-rise structures under varied seismic conditions. Moreover, while research highlights the effectiveness of combined systems, such as base isolation and innovative TMDs, under seismic and wind loads, further exploration is needed to understand their synergistic impact. Additionally, studies underscore the importance of soil-structure interaction (SSI) and partial mass isolation, yet practical integration into design frameworks is underdeveloped. Furthermore, research on the long-term durability and maintenance of these systems, crucial for their implementation in real-world scenarios, remains limited.

III METHODOLOGY

The methodology for studying the behavior of base isolation and liquid tuned mass dampers (LTMD) in multistory buildings involves a comprehensive approach to analyze their impact on structural performance under dynamic loads. Initially, a detailed literature review is conducted to understand existing research and identify gaps. The problem statement is formulated to address these gaps, focusing on enhancing seismic resilience. Advanced modeling techniques are employed using ETABS software to simulate high-rise buildings with and without base isolation and LTMD systems. Blast loading parameters are defined, and dynamic analyses are performed to evaluate structural responses. Results are analyzed and discussed to assess the effectiveness of base isolation and LTMD in mitigating seismic and blast-induced vibrations, leading to a conclusive evaluation of their benefits.

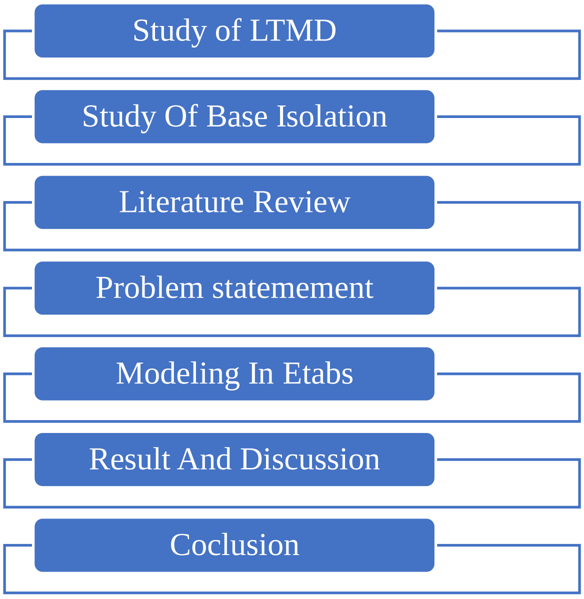


Fig 1: Flowchart

3.1 Problem Statements

The model of high-raised G+12 storey RCC structure considered for the analysis. The building is symmetrical in plane. The building has bay width of 3 m in X direction and 3 m in Y direction with 3 m storey height. Base floor height is 3 m. Liquid Tuned mass damper is installed at the roof of building. Analysis is carried out in ETABS software by Time History Analysis. A G+12 stories multi-storied building having medium grade soil is situated in Zone V on is analyzed and the displacement and acceleration with and without TMD and Base Isolation of the structure due to different load combination are obtained. For the modeling of the G+12 storey structure, following parameters are considered shown in below table I

SR.NO.	CONTENT	DESCRIPTION
1.	No. of storey	G+12
2.	Size of water tank	6X6X0.6 m
3.	Floor height	3 m
4.	Base floor height	1.5 m
5.	Wall thickness	230mm
6.	Column size	450 mm×750 mm
7.	Beam Size	300 mm×450 mm
8.	Depth of slab	150 mm
9.	Types of soil	Medium soil
10.	Seismic zone	V
11.	Zone factor	0.36
12.	Response of spectra As per IS1893(Part 1):2OO2 for 5% damping	
13.	L.L.	3 KN/m²

IV MODELLING

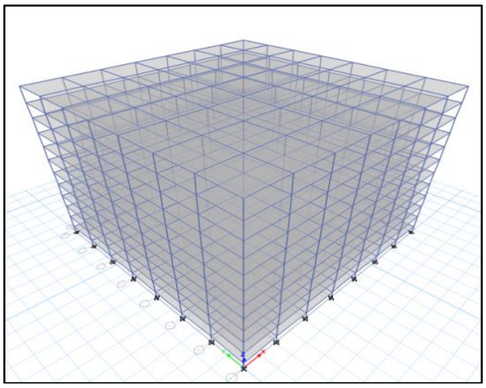


Fig. 1 Basic model 3D view

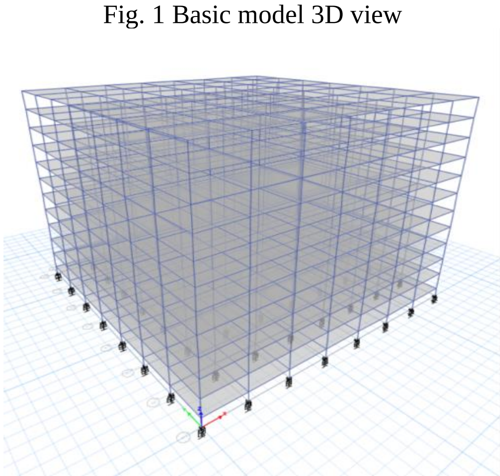


Fig. 2 Base Isolation model 3D view

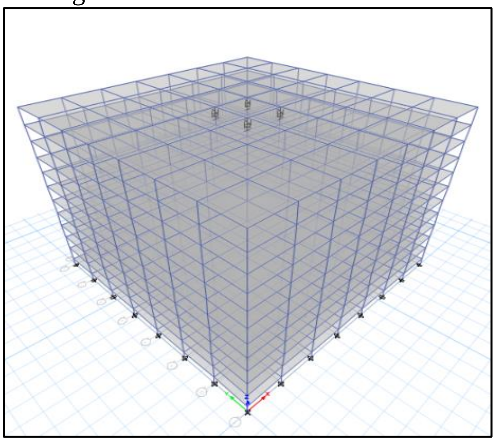


Fig 3 TMD model 3D view

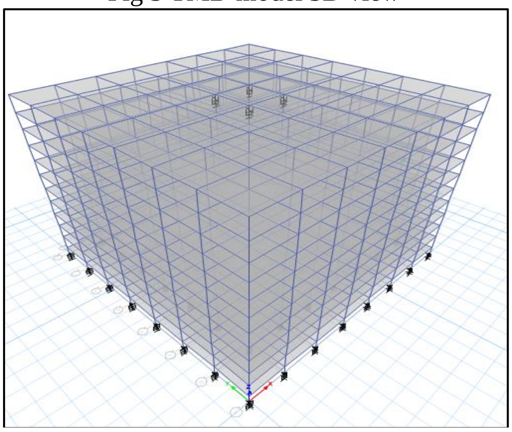
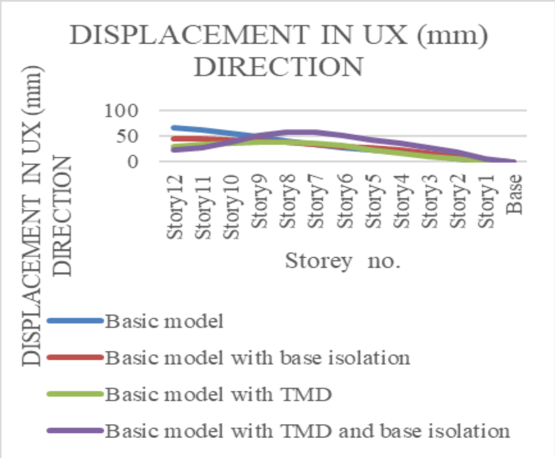


Fig 4 TMD with base isolation 3D view

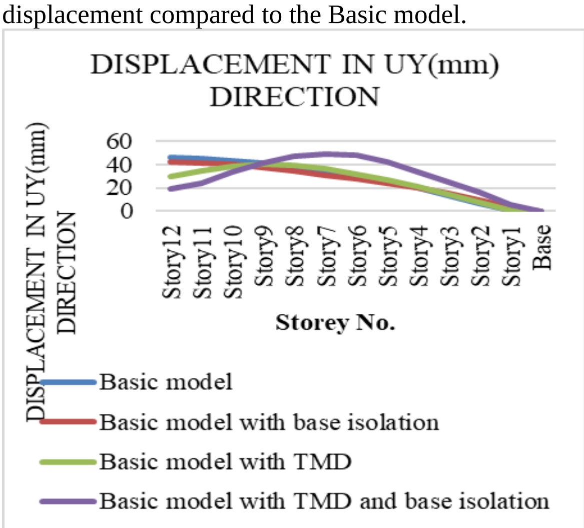
V RESULT AND DISCUSION

In this study, the analysis of multistory buildings subjected to dynamic loads highlights the effectiveness of base isolation and liquid tuned mass dampers (LTMD) in enhancing structural performance. Key metrics such as displacement, story drift, and base shear reveal that both base isolation and LTMD significantly reduce vibrations, improving stability and safety. The combined use of these techniques demonstrates superior results in mitigating seismic and wind-induced forces, ensuring the resilience and comfort of high-rise structures.



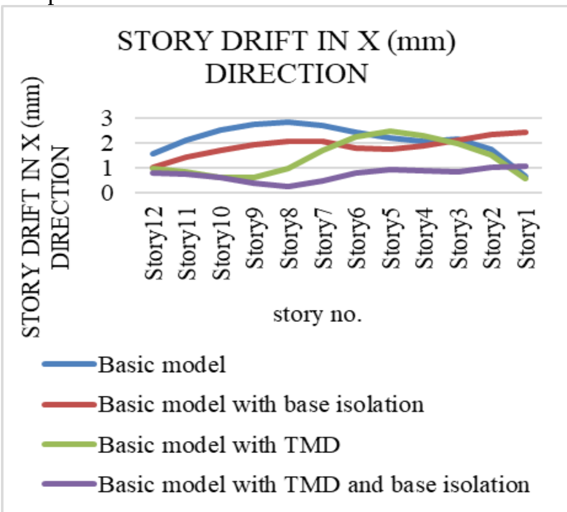
Graph1: displacement in UX (mm) direction

The above graph shows the displacement in UX (mm) for different stories of a building under four scenarios: Basic model, Basic model with base isolation, Basic model with TMD, and Basic model with TMD and base isolation. The X-axis represents the story levels from the base to Story 12, and the Y-axis represents the displacement in millimeters. The highest displacement is seen in the Basic model at Story 12 (66.287 mm), while the lowest is in the Basic model with TMD at Story 1 (0.803 mm). Both base isolation and TMD significantly reduce displacement compared to the Basic model.



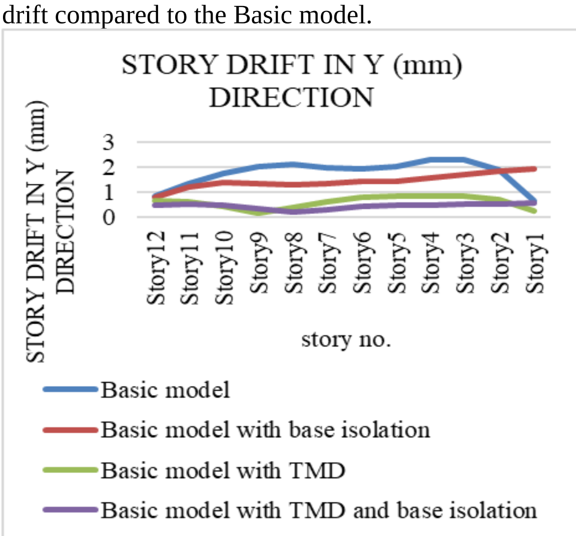
Graph 2: displacement in UY (mm) direction

The graph shows the displacement in UY (mm) for different stories of a building under four scenarios: Basic model, Basic model with base isolation, Basic model with TMD, and Basic model with TMD and base isolation. The X-axis represents the story levels from the base to Story 12, and the Y-axis represents the displacement in millimeters. The highest displacement is observed in the Basic model at Story 12 (45.947 mm), while the lowest is in the Basic model with TMD at Story 1 (1.046 mm). Both base isolation and TMD effectively reduce displacement compared to the Basic model.



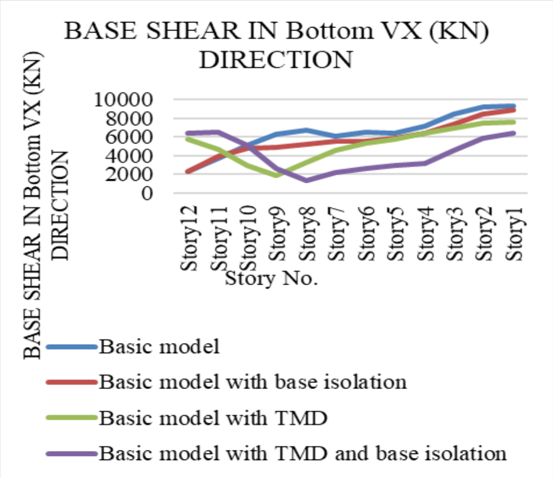
Graph 3:story drift in X (mm) direction

The above graph shows the story drift in X direction (mm) for different stories of a building under four scenarios: Basic model, Basic model with base isolation, Basic model with TMD, and Basic model with TMD and base isolation. The X-axis represents the story levels from Story 1 to Story 12, and the Y-axis represents the story drift in millimeters. The highest drift is observed in the Basic model at Story 8 (2.834 mm). The lowest drift is in the Basic model with TMD and base isolation at Story 8 (0.2425 mm). Both base isolation and TMD reduce story drift compared to the Basic model.



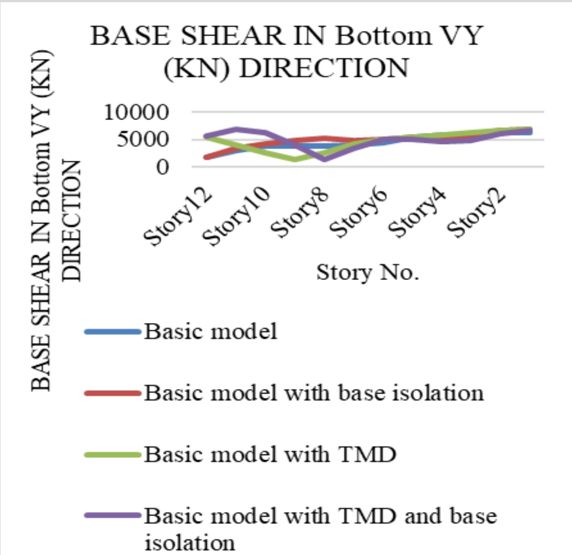
Graph 4: story drift in Y (mm) direction

The graph shows the story drift in Y direction (mm) for different stories of a building under four scenarios: Basic model, Basic model with base isolation, Basic model with TMD, and Basic model with TMD and base isolation. The X-axis represents the story levels from Story 1 to Story 12, and the Y-axis represents the story drift in millimeters. The highest drift is observed in the Basic model at Story 4 (2.277 mm). The lowest drift is in the Basic model with TMD and base isolation at Story 8 (0.16815 mm). Both base isolation and TMD reduce story drift compared to the Basic model.



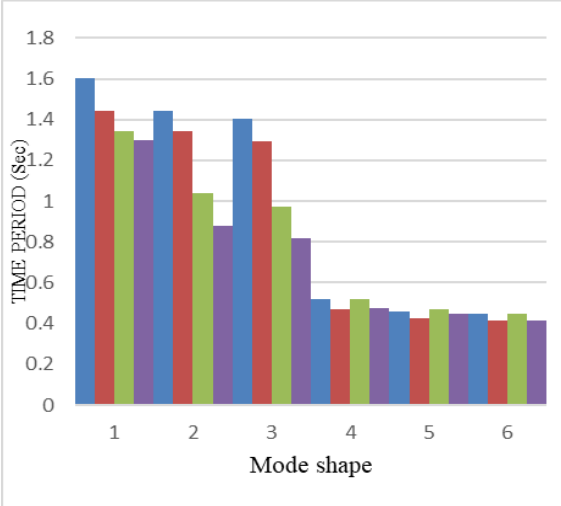
Graph 5: base shear in bottom VX (KN) direction

The graph shows the base shear in the bottom VX direction (kN) for different stories of a building under four scenarios: Basic model, Basic model with base isolation, Basic model with TMD, and Basic model with TMD and base isolation. The highest base shear occurs in the Basic model at Story 1 (9343.4922 kN), while the lowest is in the Basic model with base isolation at Story 12 (2261.45304 kN).



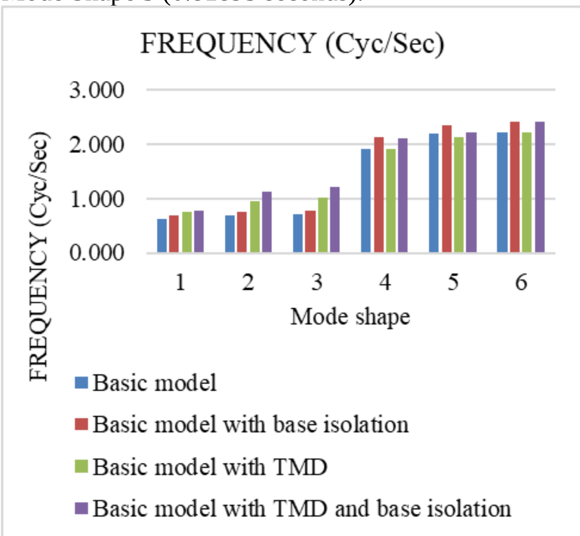
Graph 6: base shear in bottom VY (KN) direction

The graph shows the base shear in the bottom VY direction (kN) for different stories of a building under four scenarios: Basic model, Basic model with base isolation, Basic model with TMD, and Basic model with TMD and base isolation. The highest base shear is observed in the Basic model with TMD and base isolation at Story 11 (6871.76 kN), while the lowest is in the Basic model at Story 12 (1671.3442 kN). Base isolation generally increases base shear compared to the Basic model.



Graph 7: Time Period (Sec)

The graph shows the time periods (seconds) for different mode shapes of a building under four scenarios: Basic model, Basic model with base isolation, Basic model with TMD, and Basic model with TMD and base isolation. The highest time period is observed in the Basic model for Mode Shape 1 (1.601 seconds). The lowest time period is in the Basic model with TMD and base isolation for Mode Shape 3 (0.81895 seconds).



Graph 8: Frequency (Cyc/Sec)

The graph shows the frequency (cycles per second) for different mode shapes of a building under four scenarios: Basic model, Basic model with base isolation, Basic model with TMD, and Basic model with TMD and base isolation. The lowest frequency is observed in the Basic model for Mode Shape 1 (0.625 Cyc/Sec), while the highest is in the Basic model with TMD and base isolation for Mode Shape

6 (2.411 Cyc/Sec). Base isolation and TMD both increase the frequency compared to the Basic model, indicating improved stiffness and dynamic performance.

VI CONCLUSION

The study shows that base isolation and liquid tuned mass dampers (LTMDs) significantly improve the dynamic performance of high-rise buildings. Base isolation effectively minimizes seismic forces, reducing displacement and story drift, while LTMDs enhance stability by counteracting wind-induced vibrations. The combined use of these systems in high-rise buildings results in lower displacements and base shear, enhancing overall structural resilience and occupant safety. Base isolation effectively minimizes seismic forces, reducing displacement in UX from 66.287 mm to 0.803 mm and in UY from 45.947 mm to 1.046 mm, and story drift in X from 2.834 mm to 0.2425 mm and in Y from 2.277 mm to 0.16815 mm. LTMDs enhance stability by counteracting wind-induced vibrations. The combined use of these systems results in lower base shear, with reductions in the bottom VX direction from 9343.4922 kN to 2261.45304 kN and in the bottom VY direction from 6871.76 kN to 1671.3442 kN. The highest time period was reduced from 1.601 seconds to 0.81895 seconds with the implementation of these systems. These advanced modeling and dynamic analyses confirm that base isolation and LTMDs are vital for mitigating adverse effects of seismic and wind loads, ensuring the safety and comfort of high-rise buildings in both seismic and wind-prone areas.

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