|| Volume 9 || Issue 1 || 2026 || ISSN (Online) 2456-0774 INTERNATIONAL JOURNAL OF ADVANCE SCIENTIFIC RESEARCH AND ENGINEERING TRENDS

Comparative Study of Multi-Storey Building with or Without Using Active Tuned Mass Dampers

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Abstract: In recent decades, urban development has led to the construction of increasingly taller and more flexible multi-storey buildings. With increasing height, buildings become more susceptible to dynamic forces such as earthquakes, wind gusts, and human-induced vibrations, which may cause excessive lateral displacement, discomfort to occupants, and structural damage. To mitigate these dynamic effects, vibration control devices are widely used. Among these, Active Tuned Mass Dampers (ATMD) are advanced systems capable of adjusting their parameters in real time through sensors, controllers, and actuators, unlike passive systems that remain fixed. ATMDs significantly enhance the seismic and wind performance of tall buildings by reducing their dynamic response. This research focuses on the comparative dynamic behavior of a G+25 multi-storey building with and without ATMD positioned at different levels of the structure.

Keywords: Active Tuned Mass Dampers, Dynamic analysis, Wind Load, ETABS.

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I.INTRODUCTION:

To enhance the dynamic performance of structures, many vibration control methods have been developed over time. These methods are generally grouped into three categories: passive, active, and semi-active control systems. Passive control systems, like Tuned Mass Dampers (TMD), use extra mass, stiffness, and damping components to take in and reduce vibration energy from the main structure. Although passive systems are simple and don't need external power, their effectiveness is limited because their settings are fixed after installation.

Active control systems offer a more advanced and flexible way to manage vibrations. One of the best examples of this is the Active Tuned Mass Damper (ATMD). An ATMD includes a secondary mass connected to the main structure through springs and dampers, along with sensors, controllers, and actuators that adjust the system in real time based on structural movement. The sensors keep a close watch on the building's movement and send data to a control unit, which calculates the necessary force to counteract the vibrations. The actuator then applies this force to the mass damper, helping to lower the vibration levels. This ability to respond instantaneously makes ATMD systems highly effective in improving the performance of tall buildings under different conditions of dynamic loading.

The study also looks into how placing the ATMD in different parts of the building affects its ability to control vibrations, aiming to find the most efficient location. The analysis is done using structural software to model the building under earthquake conditions as per current design standards. By comparing the results from the models with and without the ATMD, this research aims to better understand the advantages of active vibration control systems in high-rise buildings. The results may help create safer and more efficient design strategies for tall buildings, especially in areas that are prone to earthquakes.

A. Tuned Mass Dampers (TMD)

Tuned Mass Dampers, or TMDs, are commonly used in structural engineering to control vibrations. They help decrease the movement of structures that are affected by dynamic forces like earthquakes, wind, machinery, and traffic. A TMD usually includes a separate mass, a spring, and a damping system that is attached to the main structure. The damping system is adjusted to match the natural frequency of the structure, allowing it to move in the opposite direction of the structure's motion. This opposite movement helps to absorb and reduce the energy from the vibrations, which in turn lowers how much the structure moves and the stress it experiences

1. Passive Tuned Mass Damper

A Passive Tuned Mass Damper is the simplest and most commonly used kind of device for controlling vibrations. It has a mass that is attached to the main structure using a spring and a damper. The system works entirely through mechanical forces and doesn't need any outside power. The way a PTMD works is based on matching frequencies.

2. Active Tuned Mass Damper (ATMD)

A Passive Tuned Mass Damper is the simplest and most commonly used kind of device for controlling vibrations. It has a mass that is attached to the main structure using a spring and a damper. The system works entirely through mechanical forces and doesn't need any outside power.

3. Semi-Active Tuned Mass Damper (SATMD)

A semi-active tuned mass damper mixes the best parts of passive and active control systems. It isn't like fully active systems, which use a lot of power to push or pull on the structure. Instead, semi-active dampers change how they work, like their stiffness or how much they resist movement, based on what the structure is doing.

4. Pendulum Tuned Mass Damper

A pendulum-tuned mass damper uses the movement of a pendulum to help control vibrations in a building. In this system, a heavy mass is attached to cables or rods inside the structure, allowing it to move freely like a pendulum.

5. Multiple Tuned Mass Damper (MTMD)

A multiple tuned mass damper system uses several smaller dampers instead of one big damper. Each damper is set to a slightly different frequency, all around the main natural frequency of the building. The main benefit of this setup is that it can handle vibrations across a broader range of frequencies.

II. PROBLEM STATEMENT

High-rise reinforced concrete buildings often show unwanted movement when subjected to earthquakes and wind. Traditional structural systems may not effectively reduce floor drift, acceleration, and sideways movement, particularly in tall and narrow buildings. While ATMD technology is commonly used in international projects, there is not much research or real-world application in India. Also, the best place to put ATMD in a multi-storey building is still being studied. Whether the ATMD should be placed at.. In this study, the building structure is designed to account for Active Tuned Mass Dampers. The building plan measures 30 meters by 30 meters and consists of 25 stories, each with a height of 3.0 meters in seismic zone III.

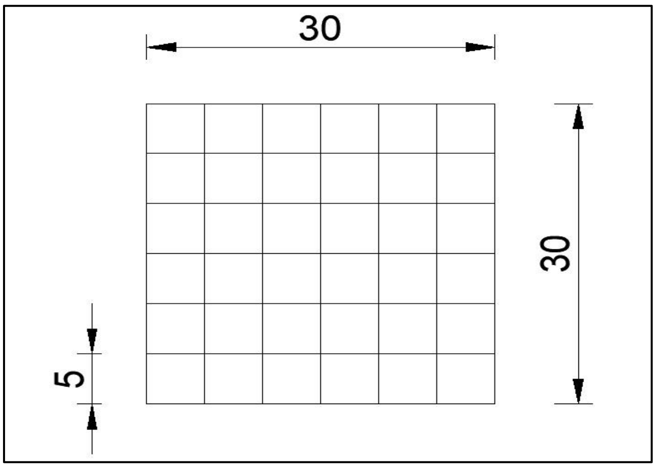


Fig 1 Plan dimensions

Table 2 Model parameters.

Number of stories	25
Bottom story height	1.5 (Meter)
Height of each stories	3 (Meter)
Area of single floor building	900 (Square meter)
Size of beam	B 450 x 450 (Millimeter)
Size of column	C 800 x 800 (Millimeter)
Slab thickness	S 150 (Millimeter)
Seismic zone	Zone III – 0.16
Response reduction factor	5.0
Importance factor	1.2
Grade of concrete	M30
Grade of steel	Fe500
Density of concrete	25 (Kilonewton per meter cube)
Supports at base	Fixed
Diaphragm	Rigid

Table 4.1 Model Details

ATMD Model	Storey Level	Height
Model 1	**Without ATMD**	**-**
Model 2	**7th Floor**	18 m
Model 3	**13th Floor**	39 m
Model 4	**25th Floor**	79.5 m

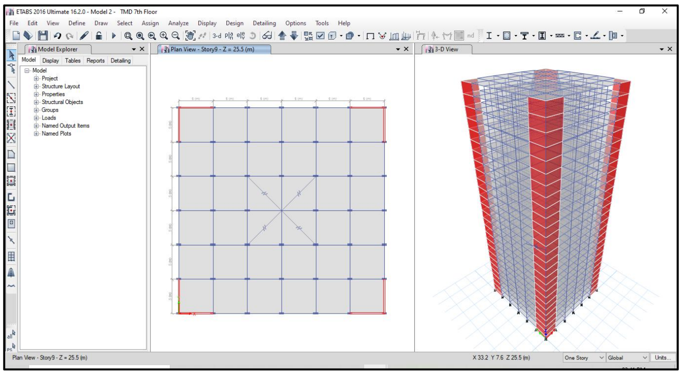


Fig 2 Modelling in ETABS

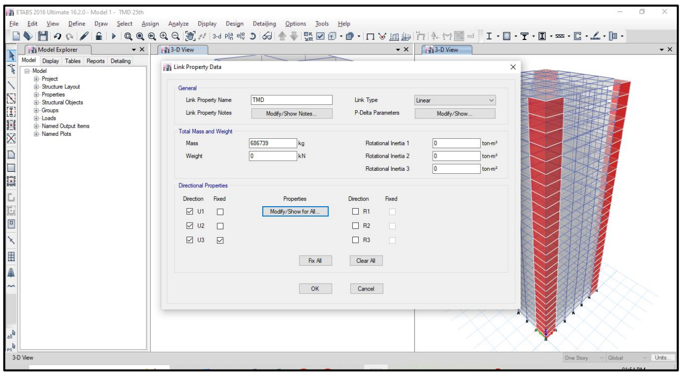


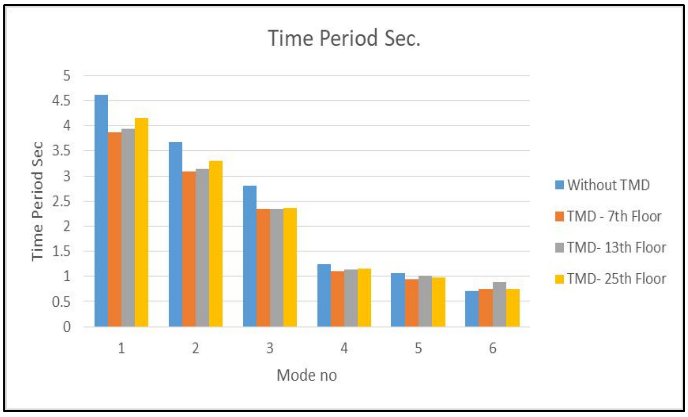
Fig 3 TMD Define in ETABS

III. RESULT AND DISCUSSION

A. Time Period Sec.

Table 3 Time Period Sec.

Time Period Sec.				
Mode	Without TMD	TMD - 7th Floor	TMD- 13th Floor	TMD- 25th Floor
1	4.609	3.866	3.936	4.152
2	3.681	3.09	3.147	3.298
3	2.801	2.338	2.344	2.365
4	1.251	1.105	1.143	1.154
5	1.059	0.946	1.011	0.982
6	0.719	0.742	0.884	0.755



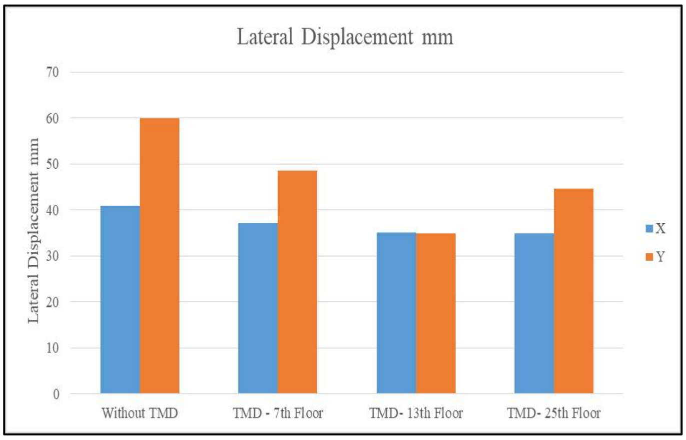
Graph 1 Time Period Sec.

Compared to Model 1 (Without TMD), the time period of the building decreases when the TMD is installed at different levels. Model 2 (TMD at 7th floor) shows an average reduction of about 13.7% in the time period, while Model 3 (TMD at 13th floor) shows a reduction of about 10.2%. Similarly, Model 4 (TMD at 25th floor) shows an average reduction of about 8.0% compared to the building without TMD. These results indicate that the installation of TMD improves the dynamic behaviour of the structure, with the 7th floor placement giving the maximum reduction in time period.

B. Result for Lateral Displacement

Table 2 Lateral Displacement mm

Lateral Displacement mm				
Direction	Without TMD	TMD - 7th Floor	TMD- 13th Floor	TMD- 25th Floor
X	40.93	37.24	35.06	34.83
Y	59.92	48.59	34.83	44.61

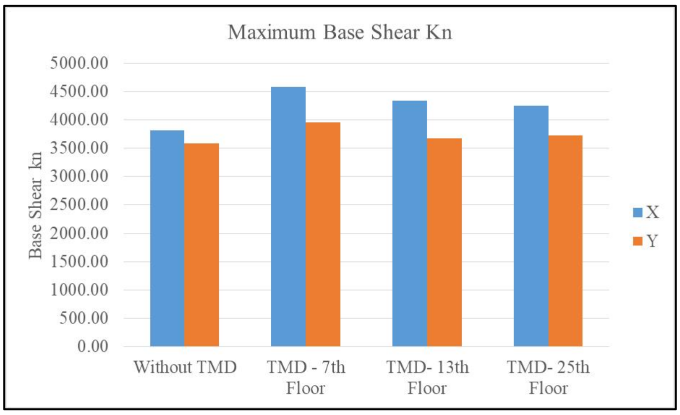


Graph 2. Lateral Displacement mm

Compared to Model 1 (Without TMD), the lateral displacement of the building decreases when the TMD is installed at different storey levels. In the X-direction, Model 2 (TMD at 7th floor) shows a reduction of about 9.0%, Model 3 (TMD at 13th floor) shows a reduction of about 14.3%, and Model 4 (TMD at 25th floor) shows a reduction of about 14.9%. Similarly, in the Y-direction, Model 2 shows a reduction of about 18.9%, Model 3 shows the maximum reduction of about 41.9%, and Model 4 shows a reduction of about 25.6% compared to the building without TMD. Overall, the results indicate that installing the TMD significantly reduces the lateral displacement of the building, with the 13th floor placement showing the most effective performance

C. Maximum Base Shear

Maximum Base Shear Kn				
Direction	Without TMD	TMD - 7th Floor	TMD- 13th Floor	TMD- 25th Floor
X	3812.81	4580.80	4338.18	4253.85
Y	3589.53	3951.27	3680.05	3727.86



Graph 3 Maximum Base Shear

Compared to Model 1 (Without TMD), the maximum base shear increases when the TMD is installed at different storey levels. In the X-direction, Model 2 (TMD at 7th floor) shows an increase of about 20.1%, Model 3 (TMD at 13th floor) shows an increase of about 13.8%, and Model 4 (TMD at 25th floor) shows an increase of about 11.6%. Similarly, in the Y-direction, Model 2 shows an increase of about 10.1%, Model 3 shows a slight increase of about 2.5%, and Model 4 shows an increase of about 3.9% compared to the building without TMD. These results indicate that the installation of TMD slightly increases the base shear due to the additional mass of the damper system.

IV. CONCLUSION

In this study, a comparison was made between a G+25 RCC multi-story building with and without an Active Tuned Mass Damper (ATMD) using ETABS software. The aim was to assess how well vibration control systems can improve the dynamic behavior of tall buildings. The ATMD was placed at three different levels: the 7th floor, 13th floor, and roof (25th floor). The structural responses of the building with and without the damper were analyzed. The findings showed that the installation of the TMD had a significant impact on how the structure behaves under dynamic forces.

- When the TMD was added, the time period of the building decreased, which suggests that the structure became stiffer and had better dynamic properties.
- The natural frequency of the building also went up, showing that the structure is more resistant to forces like earthquakes and wind.
- The lateral movement of the building in both the X and Y directions was greatly reduced when the TMD was installed.
- Among the different positions tested, putting the TMD at the 13th floor led to the biggest reduction in lateral movement, especially in the Y direction.
- The analysis of base shear showed a small increase when the TMD was added because of the extra mass from the damper.
- However, this increase was within acceptable limits and did not harm the structure's performance. In fact, the additional mass helped make the vibration control system more effective.
- The study clearly shows that active tuned mass dampers are effective in reducing structural vibrations and improving the seismic performance of multi-story buildings.
- The comparative analysis also highlights that placing the TMD at the right floor levels greatly improves the building's response. Among the tested positions, the 13th floor gave the best reduction in lateral displacement, while the 7th floor was more effective in controlling story drift.

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