

Wind-Induced Vibration Control Using Tuned Mass Damper (TMD)

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Abstract: This study aims to examine the efficacy of a Tuned Mass Damper (TMD) in reducing the vibrations, encompassing both frequency and amplitude, of a high-rise structure. The procedure was executed utilizing Ansys Workbench (Design Modeler, Mechanical). The evaluations conducted included Modal Analysis and Harmonic Response assessments for both the building independently and in conjunction with the TMD. The TMD shown efficacy in diminishing the peak amplitude and its associated frequency of the structure.

Keywords: Tuned mass damper, structure, modal analysis, harmonic response

1. Introduction

Structures, particularly tall buildings, experience vibrations due to factors such as wind, earthquakes, or anthropogenic stresses like explosions [1]. The extreme vibrations are highly undesired since they induce occupant discomfort, structural fatigue, and several possible damages, ultimately leading to structural collapse [2]. Various types of vibration management, including passive, active, and semi-active techniques, are employed to manage these vibrations [3]. Passive vibration control systems, exemplified by Tuned Mass Dampers (TMDs), employ intrinsic

material characteristics and static arrangements to dissipate energy without the need for additional power or real-time modifications [4]. They are straightforward, dependable, and economical post-installation [5]. Active vibration control systems necessitate external power, sensors for vibration detection, actuators for applying counterforces, and real-time control algorithms [6]. Although providing enhanced versatility and performance, they are more intricate and expensive [7]. Finally, semi-active vibration control systems embody a hybrid methodology. A minimal quantity of external power is

utilized to modify the characteristics of a control device (such as damper viscosity) in real-time, providing a compromise between the dependability of passive systems and the flexibility of active systems, without necessitating the application of substantial forces directly [8].

This study examines Tuned Mass Dampers (TMDs), a category of passive vibration control devices. A TMD is a secondary mass-spring-damper system calibrated to the parent structure's inherent frequency, vibrating out of phase with it via resonant interaction [9]. This substantial, out-of-phase movement efficiently absorbs kinetic energy from the primary structure, which is then dissipated as heat by the TMD's internal damping component [10]. This study seeks to examine the dynamic response of a high-rise structure subjected to harmonic forces and to assess the efficacy of an optimized Tuned Mass Damper (TMD) in alleviating excessive vibrations through Finite Element Analysis (FEA).

2. Methodology:

Utilized ANSYS WORKBENCH to analyze a structure of 160mm x 40mm x 700mm, supported by a base measuring 300mm x 100mm x 40mm. The material analyzed for the building was M30 grade concrete, with a Poisson's ratio of 0.2, Young's modulus (E) of 27,386 MPa, and a density of 2,300 kg/m³. The relevant geometry has been created in DESIGN MODELER and subsequently imported into the MODEL. A fixed support has been implemented at the base of the building in the MODEL, followed by the determination of the modal shapes. The HARMONIC RESPONSE section was subsequently extracted from the TOOLBOX section to apply wind load. A wind load with a pressure of 50 MPa has been applied to the building's facade, resulting in the corresponding frequency responses of the structure. All of these actions have been executed without the use of the damping coefficient for the building. A damping coefficient of 0.01 was subsequently chosen for the building, resulting in the frequency responses of the structure.

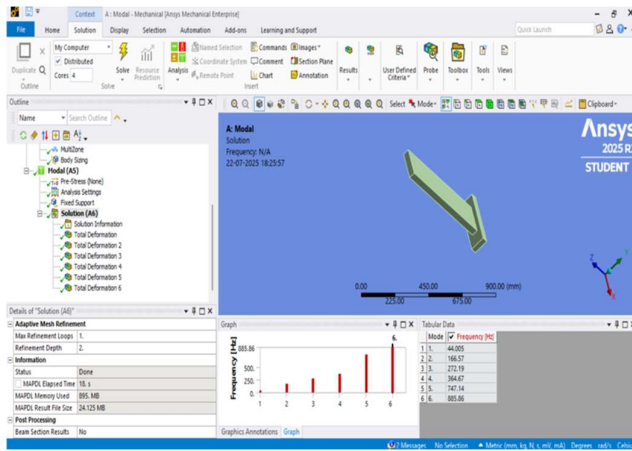


Figure 1 (a): Structure without TMD

The preceding paragraph pertains to construction without TMD. A point mass has been affixed to the upper surface of the building in ANSYS MECHANICAL. The mass of the point mass is calculated to be 2% of the entire building mass, resulting in 0.26128 kg. A spring connection has been established as BODY-GROUND. The spring exhibits a stiffness of $k = 19.974$ N/mm and a damping coefficient of 0.52189 Ns/mm. A fixed support was applied at the base of the building, followed by an analysis to obtain the modal shapes. Subsequently, as previously, the HARMONIC RESPONSE part has been extracted from the TOOLBOX section to implement wind load. Initially, the mode was altered from MODE SUPERPOSITION to FULL in the SOLVER option of ANALYSIS SETTINGS. Subsequently, a wind load with a pressure of 50 MPa was given to the

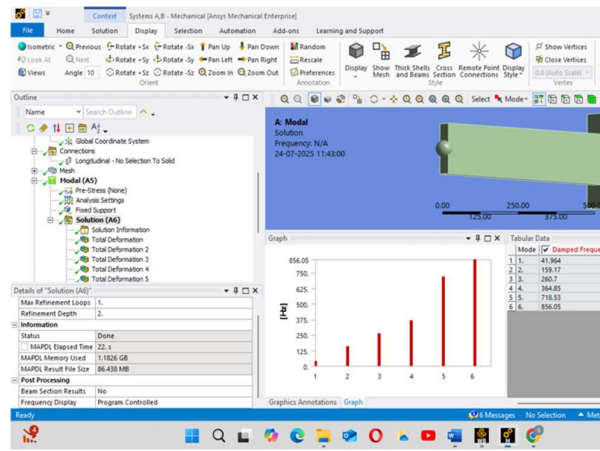


Figure 1 (b): Structure with TMD

building's facade, resulting in the frequency responses of the structure. All of these actions have been executed without the use of the damping coefficient for the building. A damping coefficient of 0.01 was subsequently determined for the building, resulting in the corresponding frequency responses of the structure.

3. Results and discussion

Table 1: Comparative analysis of frequency of structure with and without TMD

Mode	Frequency (Hz)	
	Without TMD	With TMD
1	44.005	41.964
2	166.57	159.17
3	272.19	260.7
4	364.67	364.85
5	747.14	718.53
6	885.86	856.05

Table 2: Comparative analysis of response of structure with and without TMD

WITHOUT TMD				WITH TMD			
Without damping coefficient of building		With damping coefficient of building		Without damping coefficient of building		With damping coefficient of building	
Maximum Amplitude	Frequency	Maximum Amplitude	Frequency	Maximum Amplitude	Frequency	Maximum Amplitude	Frequency
5046.9mm	57.2 Hz	1.7506e+5mm	44.001 Hz	4686.8mm	47.4 Hz	4686.8mm	47.4 Hz

5. References

- Following the application of TMD, the frequency of the associated mode forms decreased. The greatest distortion across all six modes has diminished.
- Following the implementation of TMD, the maximum amplitude decreased to 4686.8 mm, and the corresponding frequency diminished to 47.4 Hz, applicable in all scenarios (with and without the building's damping coefficient).

4. Conclusion

The TMD affixed to the upper surface of the structure has facilitated the regulation of vibrations by reducing the peak amplitude and associated frequency. Thus, the study's purpose has been achieved. Ultimately, it has augmented occupant comfort and bolstered structural integrity.

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