Controlling Seismic Excitation in the RCC Building with a Tuned Mass Damper

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ABSTRACT: The use of multiple tuned mass dampers (MTMDs) to monitor earthquake response of tall buildings is investigated. The MTMDs are located in three locations in the reinforced concrete (RC) structures. The time domain seismic analysis is performed on Etabs Software using imperial Earth movement used to analyze contemporary history. The performance of the MTMDs is compared to that of a TMD on the top floor, a TMD on the third and fifth floors, a TMD on each floor, and no TMD. The base shear vs time and displacement parameters were examined, and it was determined that the MTMDs on each floor are better for the building’s seismic response. Furthermore, it has been discovered that MTMDs are more powerful than STMDs.

Keywords: Multiple tuned mass dampers (MTMDs); Seismic Forces; Displacement; Moment resisting frame (MRF).

1. Introduction

Numerous multistory structures have been constructed as a result of rapid urbanisation. Seismic safety is important for these constructions. Efforts in this area have led to the creation of approaches such as base isolation, active control, and passive control unit. The Basic Isolation Method has been shown to be fairly effective in removing contaminants. Although the bottom-level implantation of an isolation device must be functional, it may require ongoing surveillance. Since they require a steady power source, active control methods are too costly for buildings. These gadgets will only become popular in poor nations like India if they are easy to make and inexpensive to buy. Their design strategy is up-to-date and won't require expensive maintenance or repairs. The objective of creating such a fundamental control device has been the subject of several research over the past few years. There is a basic kind of TMD suggested in these research. To minimise dynamic vibrations produced by wind or earthquakes, matching mass dampers (TMDs) are passive energy dissipation devices that connect to structures and consist of a mass, spring, and damper. There will be a concrete soft floor, and the building will have a column, beam, and slab size that is smaller than the other levels. Based on TMD (the natural frequency of TMD (soft floor) should match to that of the main building), the soft storey's height and member sizes will be calculated. [1]

It's no secret that towering buildings are on the rise. It is difficult to count the number of low-rise, medium-rise, and high-rise structures in the world today. These constructions have a low inherent damping. Increased damping capacity of structural systems, or analysing the need for additional mechanical techniques to increase damping capacity in tall and super tall buildings, has become
increasingly popular in the new generation of tall and super tall structures. Standard design practise calls for incorporating damping capacity into a structural system during construction.

As well as providing passive or active counter forces, structural vibrations generated by earthquakes or wind can be controlled by modifying rigidities, masses, damping, and form. Newly suggested structural control techniques have the potential to extend the number of applications and increase the efficiency of existing ones. Efficiency, compactness, weight, capital cost, operating cost, maintenance needs, and safety are all factors that influence the choice of vibration dampening equipment. To minimise the structure's dynamic responsiveness, TMD is linked to it. On excitation of a certain structural frequency, the damper's frequency is changed, causing the damper to oscillate out of phase with structural motion. By attaching a spring-dashpot to the mass, energy is released as a result of its relative movement with respect to the building. [2]

A. Passive Energy Dissipation

A number of variables contribute to the loss of energy in all vibrating structures. The greater the energy dissipation capacity of a vibrating structure, the smaller its vibration amplitudes. As a result, certain structures are subject to significant vibration amplitudes, even during less strong earthquakes. It is highly effective to reduce vibration amplitudes with increases in waste energy. Damping has been employed in a variety of magnification methods, and many more have been suggested. [2] Materials and technologies used in passive energy dissipation systems increase damping, stiffness, and strength, and they may be utilised to reduce the impact of natural disasters and to rehabilitate ageing structures. Sustainability technology has recently created the notion of energy dissipation, or supplementary dampening, and a number of these devices have been placed in structures throughout the world. Energies can be converted to heat or transferred between vibrating modes to achieve this. One technique uses frictional sliding, metal yielding and phase shift in a metal, solid or viscoelastic liquid deformation, and fluid opening as principles. As a dynamic vibration absorber, supplementary oscillators are utilised in the latter technique. [3]

B. Tuned Mass Damper

When mechanical vibrations occur, they are reduced in amplitude by using a TMD (matched mass damper). They avoid structural damage during a seismic event by utilising a huge mass. As a pendulum, water tank, or system composed of a huge mass, springs, and a dashpot, TMD can be utilised. This type of damper (TMD) was proposed for the first time during the 1940s [4]. Hysteresis in the primary structure is frequency-dependent due to the presence of a secondary mass with correctly regulated springs and damping components. In recent years, it has become clear that such a system is effective in reducing wind-induced structural vibration. Recent computational and experimental studies have examined the usefulness of TMDs in reducing seismic response of buildings. [5]

2. Methodology:

Multi-storey building with and without TMD. The ETABS programme is responsible for analysis and design. As a result of taking into consideration the Imperial Valley Data, the structure load is calculated by taking into account gravity loads (dead and live loads) and earthquake loads.

Time history Analysis

As a consequence, all forces and, as a result, structural displacement are calculated at identical intervals, generally 0.5 to 0.1 second.
Time-history analysis is used to study the behaviour of a structure under historical earthquake or wind acceleration data. For a structure to be an SDoF system, it must have none.

In time history studies, the structural response is calculated at a number of successive time instants. Also, the structural reaction to a particular stimulus is tracked over time. Using response spectrum analysis, it is impossible to estimate the time evolution of a response.

3. Building Description

The building model used in the research is a G+5 storey RCC construction. There are five stories in the building and each floor is five metres wide. The height of the base floor is 3 m. As a result, several kinds of tuned mass dampers are put at different locations around the structure. There are earthquake records, such as Imperial Valley Data, that may be used with ETABS Ver. 18's time linear analysis. All four seismic zones have been considered when designing the building in accordance with IS 1893:2016.

![Figure 1: Plan and 3D Assemblage of a Building](image)

| Sr. No. | Content                                  | Description                                      |
|---------|------------------------------------------|--------------------------------------------------|
| 1       | The number of floors.                    | G+5                                             |
| 2       | Height from the floor to the ceiling     | 3m                                               |
| 3       | Height of the base floor                 | 3m                                               |
| 4       | Measure the wall thickness.              | 230mm                                            |
| 5       | Imposed Live load                        | 4.5kN/m²                                         |
| 6       | Column dimension                         | 500mm x 500mm                                   |
| 7       | beam dimension                           | 230mm x 450mm                                   |
| 8       | Dimensions of the slab                   | 125mm                                            |
| 9       | Territories and soils                    | Medium (Black Cotton Soil)                       |
| 10      | Grade of Concrete/Steel                  | M20/Fe415                                        |
| 11      | Response of spectra                      | As per IS1893(Part 1):2016 for 5% damping        |
| 12      | Response Reduction Factor                | 3 (OMRF)                                        |
| 13      | L.L. On top                              | 2kN/m²                                          |
| 14      | Mass of Damper Calculated.               | 44.56 T                                         |
| 15      | Stiffness of Damper                      | 61.21 kN/m                                      |
| 16      | Damping Coefficient                      | 1.458 kN/m/s                                    |
| 17      | Damping Ratio Considered                 | 5%                                               |
Models:-

The Building modelling with and without damper is done in 4 conditions.

Damper Placement

1. Damper at Top Floor
2. Damper at 3rd and 5th Floor
3. Damper at All Floors
4. Without Damper

**Figure 2:** Damper Placement

**Figure 3:** Damper At Top Floor

**Figure 4:** Damper at 3rd and 5th floor

**Figure 5:** Damper At Each Floor

4. RESULT AND DISCUSSION:-

The result from the analysis the structure with and without damper by Etabs software with time history analysis.

1. **Base Shear Vs Time Graph**

Here the values in graph is at a time interval of 0.1 Sec.
For Damper Located at Top Floor

![Comparison of Base Shear Vs Time For DAMPER AT TOP FLOOR](image)

**Figure 6**: Baseline shift comparison Vs Time For the whole area for Damper At Top Floor

The picture above shows the Base shear vs time result for damper located at top floor for all four seismic zones. In this the maximum base shear is 0.1kN at 5.5sec for zone V. As the effect of Seismic forces is more at zone V where as it is less for other zone conditions.

For Damper Located at 3rd and 5th Floor

![Comparison of Base Shear Vs Time For DAMPER AT 3rd and 5th Floor](image)

**Figure 7**: Baseline shift comparison Vs Time For the whole area for Damper At 3rd and 5th Floor

The picture above shows the Base shear vs time result for damper located at 3rd and 5th floor for all four seismic zones. In this the maximum base shear is 0.1kN at 5.5sec for zone V. Here the base shear is almost similar for zone V for damper at top floor and 3rd and 5th floor condition but in this condition the other seismic zones has graph in the same pattern.

For Damper Located at Each Floor
Figure 8:- Baseline shift comparison Vs Time For the whole area for Damper At Each Floor

The picture above shows the Base shear vs time result for damper located at Each Floor for all four seismic zones. In this the maximum base shear is 0.17kN at 5.1sec for zone V, here the other seismic zones have graphs in the same pattern.

For Without Damper Condition.

Figure 9:- Baseline shift comparison Vs Time For the whole area for without Damper

The picture above shows the Base shear vs time result for damper located at Each Floor for all four seismic zones. In this the maximum base shear is 0.08kN at 6.7sec for zone V, here the other seismic zones have graphs in the same pattern. As here there is no damper the amount of forces generated by the earthquake will be more but the structure will not take more seismic forces. So the base shear values is the amount of force the structure can resist.

2. Displacement
For Damper Located at Top Floor

Figure 10: Comparison of Displacement for Damper at Top Floor

The picture above shows the displacement result for damper located at top floor for all four seismic zones. In this the maximum displacement of 61mm is found at zone V so the structure is displaced to a distance of 61mm for the origin when the zone V seismic forces acted on the structure.

For Damper Located at 3rd and 5th Floor

Figure 11: Comparison of Displacement for Damper at 3rd and 5th Floor

The picture above shows the displacement result for damper located at top floor for all four seismic zones. In this the maximum displacement of 57mm is found at zone V so the structure is displaced to a distance of 57mm for the origin when the zone V seismic forces acted on the structure which is less than the values of damper at top floor.

For Damper Located at Each Floor
Figure 12: Comparison of Displacement For Damper At Each Floor

The picture above Shows the displacement result for damper located at top floor for all four seismic zones. In this the maximum displacement of 49mm is found at zone V so the structure is displaced to a distance of 49mm for the origin when the zone V seismic forces acted on the structure which is less as compared to the values of Shock absorbers on the upper deck and shock absorbers at 3rd and 5th floor.

For Without Damper Condition.

Figure 13: Comparison of Displacement for Without Damper Condition.

The picture above Shows the displacement result for damper located at top floor for all four seismic zones. In this the maximum displacement of 81mm is found at zone V so the structure is displaced to a distance of 81mm for the origin when the zone V seismic forces acted on the structure which is more in comparison to the others damping condition because There is not damper to resist the seismic force.

5. CONCLUSION:-

1. A tuned mass damper (TMD) is a structure-dampening system that decreases the amplitude of mechanical vibrations. By using a large mass, they avoid structural damage during a seismic event. TMD may be used as a pendulum, a water tank, or a system consisting of a large mass surrounded by springs and a dashpot.
2. Base shear vs time graph comparison shows that the shear vs time is more in the condition where is the damper is applied at each floor.

3. Comparative deflection it is seen that the structure without shock absorbers more deflection while the structure having damper at each floor has very less deflection than the other damper conditions.

4. The conclusion of the study is damper reduces the deflection Structure after magnification the base shear vibrations within the structure.

5. When it comes to dynamic reaction control Buildings subjected to earthquake loads, MTMDs outperform STMDs.

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