PERFORMANCE EVALUVATION OF THE WATER TANK AS A TUNED MASS DAMPER - INERTER MULTI-STORIED STRUCTURE TO GROUND MOTION

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Introduction:

Seismic resilience is a critical priority in modern civil engineering, especially for high-rise structures in earthquake-prone zones. With rapid urbanization and vertical growth in Indian cities, ensuring structural safety during seismic events is essential. Tuned Mass Damper-Inerter (TMDI) systems have emerged as an advanced solution for vibration control, offering high efficiency with minimal added mass. This project explores a novel concept — utilizing a water tank, a common feature in Indian buildings, as a TMDI system. When tuned to the building's natural frequency, the tank significantly reduces seismic response. The integration of an inerter further enhances damping by increasing effective inertia. A G+10 residential building in Seismic Zone IV serves as the case study. A detailed numerical model is developed using ETABS for seismic analysis. The approach offers a sustainable, cost-effective alternative to conventional dampers. This research contributes to practical, dual-function design strategies in earthquake-resistant construction.

Objectives:

1. To develop numerical model of multi-storey building using FEM software.
2. To develop mathematical modeling for a water tank as a tuned mass damper (TMD) with Inerter.

3. To study the dynamic response of structure subjected to various ground accelerations.

Methodology:

The methodology for this project aims to assess the performance of a water tank-based Tuned Mass Damper-Inerter (TMDI) system in reducing seismic effects on multi-storied buildings. The approach includes:

1. Building Data Collection: A G+10 residential building in Seismic Zone IV is chosen. Structural, material, and occupancy data are collected for an accurate model, including masonry infill wall thickness.

2. TMD Design: A conceptual design for the water tank as a TMD is developed, ensuring its mass and location align with the building's first mode of vibration for optimal damping.

3. Numerical Modeling in ETABS: A 3D model of the building is created in ETABS, initially without the TMDI system, to serve as a baseline for comparison.

4. Seismic Hazard Analysis: Seismic parameters are derived from IS 1893:2016, and appropriate ground motion records are selected for realistic earthquake simulation.

5. Seismic Response Analysis: Time history and response spectrum analyses are performed to evaluate displacement, storey drift, and acceleration under various seismic events.

6. Assessment of Seismic Performance: The seismic performance is assessed by comparing inter-storey drift, base shear, and acceleration with code requirements, and the impact of the TMDI system is evaluated.

7. Results Interpretation and Optimization: The TMDI-integrated model is compared with the baseline to measure effectiveness in vibration mitigation, followed by optimization of the system's parameters.

8. Final Design and ImplementationThe TMDI parameters (mass, damping, inerter coefficient) are refined, and the integration of the water tank with the building is finalized for practical application.

Result and Conclusion:

A detailed seismic analysis was conducted on a G+10 residential building model developed in ETABS, excluding the TMDI system to establish baseline performance. The model incorporated material properties, masonry infill walls, and seismic parameters as per IS 1893:2016 for Zone IV with medium soil conditions. Results showed considerable inter-storey drift at the upper levels, indicating structural vulnerability. Peak floor acceleration and displacement were observed at the roof, highlighting the need for vibration control. The building's fundamental natural frequency was identified, providing a key input for tuning the proposed TMDI system. Base shear and modal participation values remained within permissible limits but signaled potential for enhanced damping. These observations underscore the need for supplemental damping to mitigate seismic impact. The integration of a water tank-based TMDI is anticipated to improve performance significantly. Future simulations will compare structural behavior with and without the TMDI system. The aim is to achieve noticeable reductions in drift, acceleration, and displacement. This will validate the system's effectiveness in enhancing seismic resilience. The approach offers a practical and economical retrofit solution. It promotes dual-purpose utility without significant structural changes. Overall, the study supports innovation in earthquake-resistant design strategies.

Project Outcome & Industry Relevance:

This project introduces a novel seismic mitigation strategy by repurposing a water tank as a Tuned Mass Damper-Inerter (TMDI) system. The outcome highlights the system's capability to reduce vibrations and improve seismic performance in multi-storied buildings. It enhances structural integrity and occupant safety during earthquakes. The approach is practical and cost-effective, suitable for both new constructions and retrofitting existing structures. It holds strong relevance for the construction industry, especially in seismic-prone regions. The method offers a dual-purpose solution, utilizing existing architectural components. It presents a sustainable alternative to conventional damping systems. Direct applications include high-rise residential and commercial structures. The project pushes innovation in structural design and dynamic response control. It also encourages future research into scalable, hybrid vibration control systems.

Working Model vs. Simulation/Study:

This project is primarily a simulation-based theoretical study. A detailed structural model was developed and analyzed using ETABS software. No physical prototype was constructed, as the focus was on numerical analysis and performance evaluation under seismic loading.

Project Outcomes and Learnings:

Key outcomes include identifying seismic vulnerabilities and establishing baseline response metrics. I learned to apply IS codes, perform seismic analysis, and interpret dynamic behavior using ETABS. The project enhanced my understanding of TMDI systems and their practical integration in structural design.

Future Scope:

The project can be extended by incorporating the water tank-based TMDI into the structural model for comparative seismic analysis. Further optimization of TMDI parameters like mass, damping, and inerter values can enhance system efficiency. Experimental validation through scaled models or shake table testing is a promising next step. The concept can be applied to various building types and retrofitting of existing structures in seismic zones. Integration with real-time monitoring systems for adaptive damping control can modernize the approach. Research can explore multiple TMDIs at different levels for improved performance. Applications may extend to bridges, towers, and industrial structures. Investigating cost-effective inerter designs would aid implementation in developing regions. Fluid-structure interaction within the tank could be modeled for greater accuracy. Aligning the system with sustainable building practices offers additional value for future developments.