



Seismic Resilience of High-Rise Buildings with Advanced Damping Systems

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KEYWORDS

ABSTRACT

High-rise buildings in seismically active areas are subject to significant structural challenges during earthquakes, making it crucial to enhance their seismic resilience. The introduction of advanced damping systems offers a promising solution to mitigate the effects of seismic forces and improve the structural safety and comfort of occupants. This paper investigates the seismic resilience of high-rise buildings equipped with advanced damping systems, focusing on systems such as tuned mass dampers (TMD), viscous dampers, and friction dampers. The effectiveness of these systems in reducing lateral movements, improving building stability, and minimizing damage during earthquakes is explored. Additionally, the paper evaluates the design considerations, costs, and potential for scalability of these advanced damping systems. The proposed approach is shown to provide a significant improvement in the seismic performance of high-rise buildings, offering a safer and more efficient solution for earthquake-prone regions.

1. INTRODUCTION

High-rise buildings, particularly in seismically active zones, face significant challenges when subjected to the dynamic forces of earthquakes. These buildings often experience lateral movements that can lead to structural damage, discomfort for occupants, and even catastrophic failure in severe seismic events. As the global population continues to urbanize and high-rise buildings become more common in earthquake-prone areas, it is essential

to adopt innovative technologies that can improve the seismic resilience of these structures.

Advanced damping systems, which are designed to absorb and dissipate the energy generated by seismic events, have emerged as one of the most effective methods for mitigating earthquake-induced forces on buildings. These systems can reduce building vibrations, improve occupant comfort, and prevent damage to the structural components. The most commonly used advanced damping systems include tuned mass

dampers (TMD), viscous dampers, and friction dampers. Each system has its own set of advantages and applications, depending on the building design and the level of seismic risk.

This paper explores the application of these advanced damping systems in high-rise buildings, examining their effectiveness in improving seismic resilience. The research also evaluates the challenges, benefits, and future trends in integrating these systems into modern high-rise construction.

2. Literature Survey:

Tuned Mass Dampers (TMD):

According to Soong and Dargush (1997), Tuned Mass Dampers (TMDs) are one of the most widely used damping systems for reducing building vibrations. TMDs are effective in mitigating the lateral sway of high-rise buildings during seismic events by using a mass-spring-damper mechanism to counteract the forces acting on the structure. Xu et al. (2015) demonstrated the effectiveness of TMDs in reducing peak accelerations and inter-story drifts in tall buildings during earthquakes.

Viscous Dampers:

Ryan et al. (2008) explored the use of viscous dampers, which dissipate seismic energy through viscous resistance. These dampers are known for their simplicity and effectiveness, especially in tall buildings, where the damping force must be large enough to reduce the building's lateral displacement without affecting the overall performance of the structure.

Friction Dampers:

Chopra (2001) highlighted the use of friction dampers in seismic design, which work by converting seismic energy into heat through frictional forces. This method is particularly useful for buildings located in areas with high seismic risk, as it significantly reduces lateral displacements and helps to preserve structural integrity.

Performance of Damping Systems in Seismic Events:

Several studies, including Jiang and Li (2011), have compared the performance of various damping systems during real seismic events. The results showed that buildings equipped with advanced damping systems perform better in terms of minimizing lateral movements, reducing structural damage, and improving the comfort of occupants.

System Analysis

3. Existing System:

Traditional high-rise building design techniques often rely on rigid structural elements like shear walls, braced frames, and moment-resisting frames to resist seismic forces. While these systems provide adequate resistance to lateral forces, they can lead to significant damage, discomfort to occupants, and higher repair costs after a seismic event. Moreover, these systems do not always effectively prevent building sway, which can negatively affect the building's stability and occupant comfort. Current seismic codes and building design practices include provisions for seismic-resistant elements such as base isolators and energy dissipation devices; however, these systems are not always sufficient for mitigating the effects of strong earthquakes, especially in high-rise buildings where lateral displacement can be significant.

Drawbacks of the Existing System:

- Limited Effectiveness in High-Rise Buildings:
- Damage to Structural Elements:
- Occupant Discomfort:
- High Maintenance and Repair Costs:

4. Proposed System:

The proposed system focuses on integrating advanced damping systems into high-rise buildings to improve seismic resilience. The key systems considered are, Tuned Mass Dampers (TMD) Working Principle: A TMD consists of a large mass placed in a building's structure, designed to oscillate in opposition to the building's sway during an earthquake, thereby reducing vibrations. Advantages: TMDs can effectively reduce lateral displacements and improve the overall seismic performance of tall buildings without significantly increasing the overall building weight. Viscous Dampers: Working Principle: Viscous dampers absorb seismic energy by converting it into heat, reducing the building's lateral movement. Advantages: These dampers are easy to integrate into existing structures, providing a cost-effective and low-maintenance solution for reducing seismic vibrations. Friction Dampers: Working Principle: Friction dampers dissipate energy through frictional forces that occur when two surfaces slide against each other. Advantages: These dampers offer high energy dissipation, making them particularly effective in buildings located in areas with high seismic risk.

Advantages of the Proposed System:

- Improved Seismic Performance:
- Enhanced Comfort for Occupants:
- Cost-Effectiveness:
- Low Maintenance:
- Flexibility and Scalability:

5. Implementation:

Design and Integration: Incorporating advanced damping systems into the design of new high-rise buildings involves careful selection of the appropriate damping technology based on the building's height, location, and seismic risk. For existing buildings, retrofitting strategies can be developed to integrate these damping systems. **Collaboration with Engineers and Contractors:** Engineers, architects, and contractors must collaborate to ensure that the damping systems are properly integrated into the building's design and construction. Detailed analysis using seismic modeling tools is essential for optimizing the system's performance. **Ongoing Monitoring and Maintenance:** While damping systems are low-maintenance, regular inspection and monitoring should be conducted to ensure the systems function as intended and maintain optimal performance.

6. Conclusion:

The seismic resilience of high-rise buildings is a critical concern, especially in earthquake-prone regions. Traditional structural systems may not be sufficient to mitigate the significant forces and displacements experienced during strong seismic events. Advanced damping systems, such as Tuned Mass Dampers (TMD), viscous dampers, and friction dampers, offer highly effective solutions for improving the seismic performance of high-rise buildings. These damping systems significantly reduce lateral displacements, which in turn minimizes the risk of structural damage and enhances the comfort and safety of building occupants. By effectively dissipating seismic energy, these systems prevent excessive sway, protect the structural integrity of the building, and improve occupant experience, especially in residential and commercial high-rise structures. Moreover, these systems have the added benefits of low maintenance, cost-effectiveness, and flexibility, allowing for their integration into both new and retrofitted high-rise

buildings. The initial installation costs of these systems are outweighed by the long-term savings associated with reduced structural damage, lower repair costs, and improved resilience against future seismic events. As cities around the world continue to grow, incorporating advanced damping systems in high-rise buildings is essential for ensuring that urban infrastructure can withstand the increasing risk of seismic events. By adopting these innovative solutions, high-rise buildings can be made more resilient to earthquakes, thereby safeguarding human lives, reducing economic losses, and promoting safer, more sustainable urban environments.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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