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Chapter 5

Evaluating the impact of seismic resilience of telecommunication tower by using time history analysis for with and without viscous damper

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Abstract:

The seismic behavior of viscous-damped telecommunication towers is evaluated using time history analysis. It is shown that the relative maximum peak displacement could be reduced to levels as low as 23% having an average 3% rise in acceleration as an acceptable trade-off. In the present study, dynamic time history analysis performed more effectively than the equivalent static analysis; even responses were significantly reduced in both X and Y directions. Peak displacements were thereby reduced by up to 77.6% and 94% in the X direction and by 94% and 78% in the Y direction, depending on the measurement point. Secondary analysis indicated that with the introduction of dampers displacements in the X and Y directions decreased by 62–82% and 61–81%, respectively. These results prove that the viscous dampers are a good application meant to neutralize effects from seismic forces, enhancing the structural system's resilience and ensuring the integrity of critical telecommunication infrastructure in seismic areas. The results show the value added by the viscous dampers to operational continuity and structure safety during the seismic event.

Keywords: Seismic behavior, Maximum peak displacement, Seismic forces, Viscous-damped telecommunication tower, Time history analysis.

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5.1 Introduction

Telecommunication towers are critical infrastructure (Pathrikar et al., 2017). They maintain the communications networks (Pathrikar et al., 2017), which can be used for everyday communications as well as emergency response (Rajasekharan et al., 2014). The seismic activity in regions creates a need to address such structural integrity in towers as it needs to withstand ground motion forces and continue to operate effectively (Ghodrati et al., 2007). Earthquakes can cause significant displacement and acceleration responses of tower structures (Amiri et al., 2004), thus impacting their stability and operational capacity (Amiri et al., 2004). These can be mitigated with improved seismic resilience of telecommunication towers by detailed analyses and strategic applications of seismic control devices such as viscous dampers (Rajasekharan et al., 2014).

Time history analysis is a method of dynamic structural analysis carried out to simulate the response of structures to earthquake ground motion (Oliveira et al., 2007). A recorded or synthesized accelerogram is applied to the structural model (DiSarno et al., 2008). Engineers can thus check peak displacement and acceleration, two parameters indicative of response in terms of structural performance during earthquake events (DiSarno et al., 2008). This study, by analysis, could show how towers respond under various conditions (Amiri et al., 2004), with research scientists and engineers being able to investigate the effects of seismic control devices on the entire resilience of the structure (Amiri et al., 2004). The concept of a digital twin can be extended to seismic exploration, offering a virtual representation that can simulate and predict geological phenomena, thereby aiding in risk management and decision-making (Patil et al., 2024; Rane et al., 2024a; Rane et al., 2024b; Rane & Paramesha, 2024; Rane & Shirke, 2024).

Under seismic loading, time history analysis is carried out with and without viscous dampers on the telecommunication towers (Oliveira et al., 2007). Thereby (Pathrikar et al., 2017), it is dealt with in detail since both of them are of interest (Oliveira et al., 2007). For example, (Pathrikar et al., 2017) a major performance metric applied to such studies are peak displacement and acceleration due to the fact that they define the degree of displacement and forces that will be encountered by the tower during an earthquake event (Ghodrati et al., 2007). Very high peak displacement values may cause instability in structures (Ghodrati et al., 2007); high acceleration can cause mounted equipment to become unstable and produce adverse effects in the functioning of towers (Pathrikar et al., 2017). Viscous dampers are passive energy dissipation devices that are designed to dissipate vibrational energies in structures (Pathrikar et al., 2017). They reduce these adverse responses with broadly minimizing the amplitudes of the remaining vibration (More et al., 2019).

It aims to minimize peak displacement as well as peak acceleration so that the tower does not deteriorate during seismic events and it remains safe structurally (Ramdas et al., 2022). If the viscous damper is properly integrated in the telecommunication towers (Ramdas et al., 2022), they will reduce the amplitude of the vibration by dissipating energy from the seismic waves thereby lowering the peak response ensuring that all the important parts and equipment do not move beyond their limits (Ras et al., 2016). This attempt aims to evaluate the seismic response of telecommunication towers with and without dampers in order to carry out the assessment towards their effectiveness in providing seismic resilience (Ras et al., 2016).

Findings from this research shall be contributed for developing better design and retrofit strategies for seismic regions telecommunication towers (Tiwari et al., 2023). The results will therefore provide a base for the implementation of effective damping systems (Infanti et al., 2008), protect fundamental communication infrastructures, and ensure service continuity during and after the occurrence of earthquakes(Tiwari et al., 2023). This study has focused on peak displacement and acceleration measures under seismic resilience and how time history analysis can be used to guide damping solution application to enhance structural performance under seismic loading (Infanti et al., 2008).

5.2 Viscous Dampers

Viscous dampers are generally considered to be one of the best methods of suppressing dynamic vibrations in structures affected by the forces of earthquakes(Umachagi et al., 2013), wind loads, and even other dynamic excitation (Umachagi et al., 2013). Generally, such devices work by dissipating the amount of energy introduced within a structure through external forces that may range from (Marko et al., 2004), but are not limited to, effects of earthquakes, wind forces, and traffic movements (Marko et al., 2004). Viscous dampers enhance general performance and strength of design requirements for buildings (Balkanlou et al., 2013), bridges, and other civil engineering structures such as telecommunications towers (Rajasekharan et al., 2014), mainly through the reduction in vibration amplitudes and control of structural response (Marko et al., 2004). Viscous dampers, therefore are supplementary elements in the seismic design process (Marko et al., 2004), enhancing a structure's capability to resist the dynamic load exerted by earthquakes (Ras et al., 2016). Traditional methods include alterations made to increase structural stiffness, or adding reinforcement (Ras et al., 2016); however although they may be effective, they tend to increase cost (Tiwari et al., 2023), or weight. Viscous dampers (Tiwari et al., 2023), however, have inherent properties and tend to reduce seismic energy dissipation in the most cost-effective and efficient means of reducing mass without significant rises in the structure's mass(More et al., 2019). Thus, optimized designs well balanced in terms of performance, safety, and cost-effectiveness (More et al., 2019).

Viscous dampers are proven technology in enhancing the seismic resistance of a structure through dissipating dynamic forces like earthquake (Rajasekharan et al., 2014). Such devices diminish the shear generated on the foundation, decrease story displacement (Ramdas et al., 2022), and control story drift (Ramdas et al., 2022), thus making telecommunication towers and important critical infrastructure survive seismic events in safety and functionality (Rajasekharan et al., 2014). The rising application of viscous dampers in contemporary seismic design has been an indicator of how these devices seriously contribute to improving the structural performance and the risk of failure in earthquake-prone regions (Pathrikar et al., 2017).

5.3 Material property and modelling

It develops and validates the structural model at both linear and non-linear static tools for the evaluation of chosen mathematical models (Pathrikar et al., 2017).. To assure the accuracy and practicality of this research, it did require basic assumptions with relevant geometric considerations as seen in this dissertation with the necessary material parameters (More et al., 2019). This highly mathematical model captures the non-linear behavior of parts in the structure (Pathrikar et al., 2017). In this work, the elastic flexural hinges do contain the elements of plasticity to model the frame parts just to realistically display the material's behavior under stress (Pathrikar et al., 2017). This chapter briefly describes the process of the non-linear modeling of framed structures including techniques that have been applied to realistically represent inelastic reactions (Tiwari et al., 2023).

The object of this research work is to study actual life service and the performance of structures for telecommunication towers under seismic loading. A simple design approach is adopted here with minimal complications to the model in order to have a realistic response from the structure. The paper compares the seismic behavior between two models of a telecommunication tower: one model without a damper and one model with a damper, to determine whether differences exist in seismic behavior between the two. Utilizing the effect of the earthquake loading through the software SAP 2000 version 18.2.4. Height is set at 56 meters, tapering design, with the base at 10 x 10 meters and tapering down to 2 x 2 on top. The models are prepared structurally; dampers were placed in one instance in order to furnish the real comparison of seismic performance and realistic response characteristics of the tower with and without damping. Indian standard rolled steel angle section for tower construction Here, ISA-200x200x25mm column leg and bracing of tower is done using ISA 100x100x12mm. The stress stain relationship that has been used according to IS:800:2007; Basic material properties for the tower structure: Dimension of Model Plans: The minimum plan dimension of the tower model is 10 meters by 10 meters. Dimension of Top Plans of Model: The dimension at the top plan is reduced to 2 meters by 2 meters. Height of Tower: The overall height of the tower is 56 meters. Material Properties: Specific material properties include descriptive definitions of the structure. Leg Member: The leg members are prepared with ISA sections 200 by 200 mm and 25 mm of thickness. Bracing Member: Bracing members make use of the ISA sections of size 100 by 100 mm and 12 mm of thickness. Bracing Type: Bracing in the tower is of the type of concentric and eccentric bracing type. Soil Types: The types of foundation soils adopted include hard, medium, and soft soils. Seismic Zones: The study considers seismic zones II, III, IV, and V; accordingly, it will cover all the seismic zones. Response Spectrum (R): R value for the response modification factor, is considered as 4. Importance Factor (I): Importance factor taken for this critical infrastructure is 1. Grade of Steel: Fe-345 hot rolled steel sections will be used for the structural works Platform Load on Tower: The load on the tower due to the platform is taken as 1 kN per square meter. Damper Stiffness: The installed viscous dampers have a stiffness of 1645 kN per meter. Load on Tower - Antennas: CDMA Antennas: There are 8 no. of CDMA antennas, dimensions being 0.26 meters by 2.5 meters and weighing 20 kg. Microwave Antennas (Type 1): There are two microwave antennas with diameter 1.2 meters and each weighing 77 kg. Microwave Antennas (Type 2): There are three microwave antennas of diameter 0.6 meters, and each weighing 45 kg. Microwave Antennas (Type 3): Four microwave antennas, with a diameter of 0.3 meters, and all of them weigh about 25 kg. Total Joint Load The total joint load on the telecommunication tower is calculated as follows: 50 kN.

5.4 Time History Analysis

It is a dynamic analytical approach that can be adopted in order to check the seismic performance of structures by taking input from realistic or simulated ground motion along the time history IS: 1890-2002 (Part-1). This can provide a great amount of information regarding how seismic forces may affect the stability of structures IS: 1890-2002 (Part-1), with critical structures such as telecommunication towers having the need to remain in operation both during and after an earthquake IS: 1890-2002 (Part-1). With such analysis of peak displacement and acceleration, the engineers can be able to evaluate the behavior of the tower under seismic loads and determine whether any areas need structural reinforcements IS: 1890-2002 (Part-1).

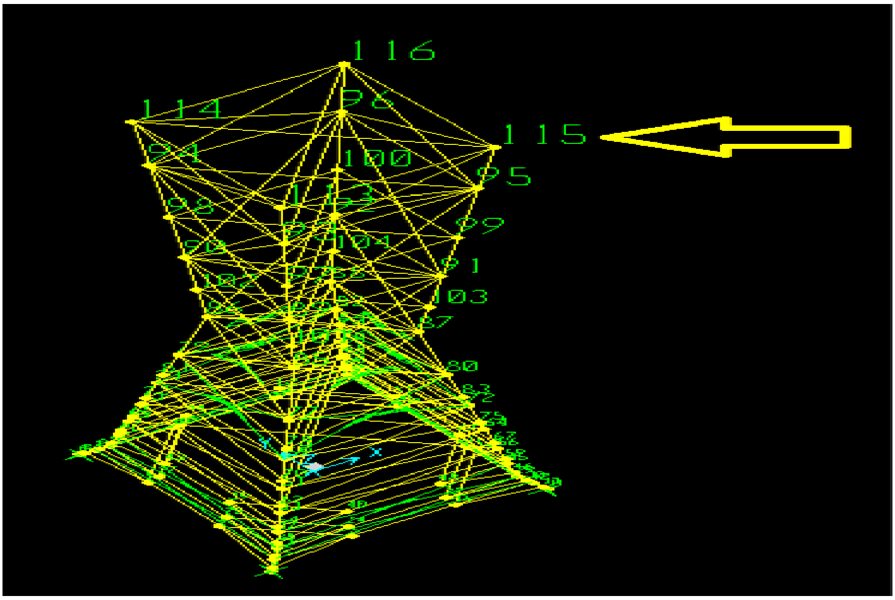


Fig 5.1 showing joints 15

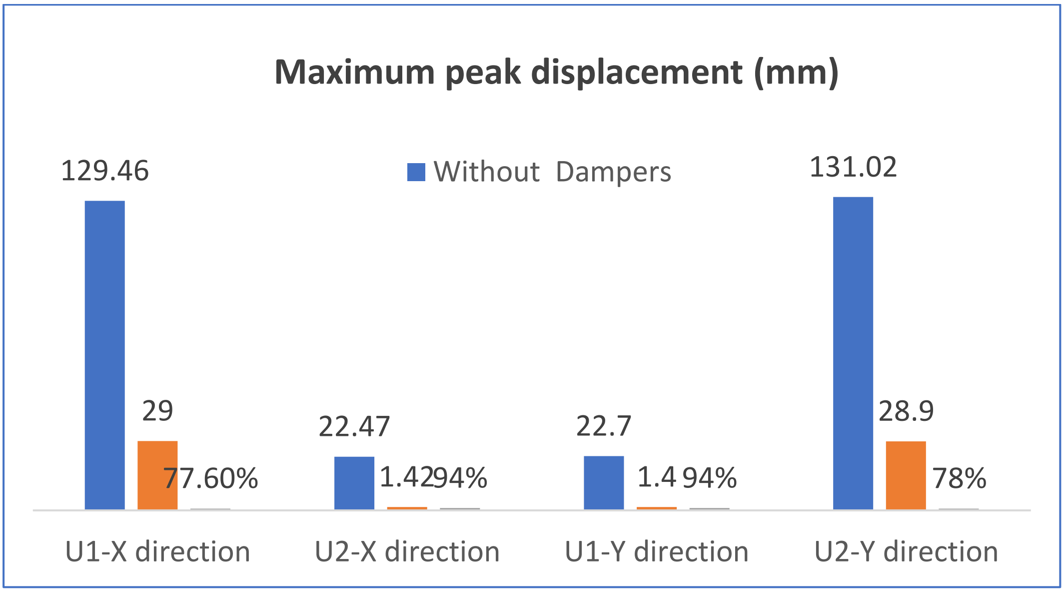
Seismic responses in such thin, high-tension telecommunication towers especially those that contain a range of antennas and equipment are likely to be heightened because of their height IS: 1890-2002 (Part-1). The time history analysis will give insight into these responses, particularly the flexibility and damping capacity of the tower IS: 1890-2002 (Part-1), which are essential in reducing the vibrations that may otherwise cause operational disruption or structural damage IS: 1890-2002 (Part-1). The analysis is quite insightful in the assessment of the impact of seismic control devices, such as viscous dampers IS: 1890-2002 (Part-1), used to absorb and dissipate seismic energy, thus minimizing displacements and accelerations in the structure during earthquakes IS: 1890-2002 (Part-1).

5.5 Results and Discussion

Table 5.1 Maximum peak displacement (mm) for time history analysis

DIRECTION	Without Dampers	With Dampers	% Reduction
U1-X direction	129.46	29	77.6%
U2-X direction	22.47	1.42	94%
U1-Y direction	22.7	1.4	94%
U2-Y direction	131.02	28.9	78%

From the above table shows peak displacement for both without and with damper for time history analysis the displacement is more tower without damper compared to with damper. Along X-direction displacement reduces to 100.46mm, along Y-direction 21.3mm.

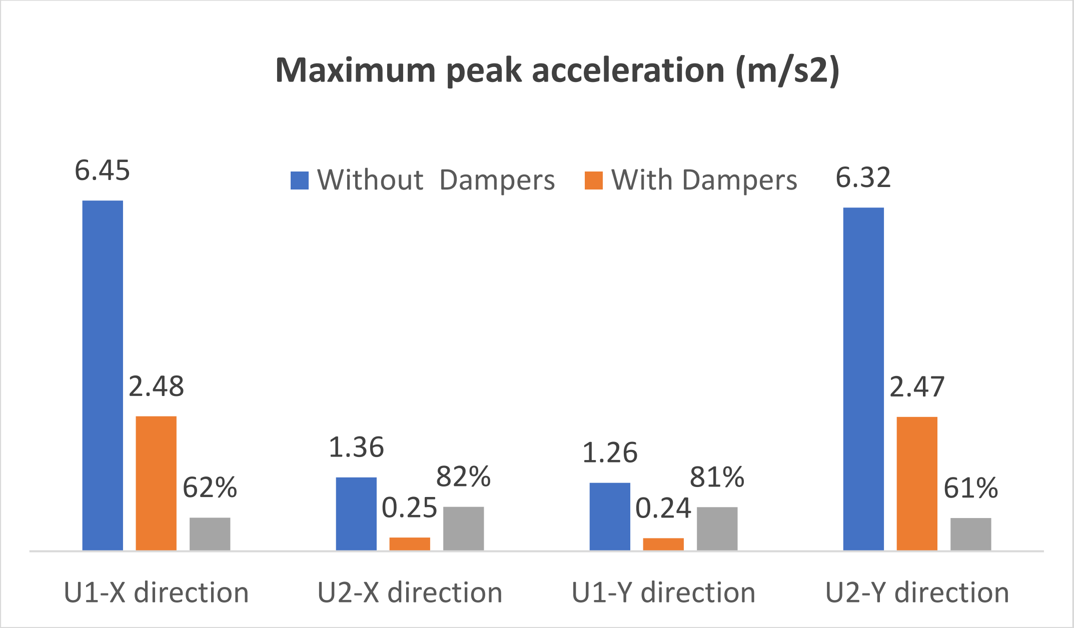


From the above graph shows peak displacement for both without and with damper for time history analysis the displacement is more tower without damper compared to with damper. Along X-direction displacement reduces to 100.46mm and along Y-direction is reduced 21.3mm.

Table 5.2 Maximum peak acceleration (m/s^2) for time history analysis

DIRECTION	Without Dampers	With Dampers	% Reduction
U1-X direction	6.45	2.48	62%
U2-X direction	1.36	0.25	82%
U1-Y direction	1.26	0.24	81%
U2-Y direction	6.32	2.47	61%

From the above table maximum peak acceleration values are more for without damper compared to with damper and maximum reduction of peak displacement values along Y-direction compared to X-direction is about 82%. Hence it can be concluding that with damper in tower model values for both displacements as well as acceleration decreases compared to without damper.



From the above figure maximum peak acceleration values are more for without damper compared to with damper and maximum reduction of peak displacement values along Y-direction compared to X-direction is about 82%. Hence it can be concluded that with damper in tower model values for both displacement as well as acceleration decreases compared to without damper.

5.6 Conclusion

From time history analysis, it can be concluded that 77% of maximum peak displacement can be reduced, with the introduction of dampers, and due there will be slight increase 3% in the acceleration due to effect of dampers in the towers which is allowable. Dampers will have more effect in dynamic analysis compared to Equivalent static. Hence from the present study, it can be concluded that the overall performance and stability of the telecommunication tower can increased with the introduction of the damping system. The results of the time history analysis of the telecommunication tower show that the inclusion of viscous dampers leads to a drastically improved seismic performance in all directions by reducing the displacement. In X direction, the peak values of displacement were reduced by 77.6% (U1) and 94% (U2); in the Y direction, reductions reached 94% (U1) and 78% (U2). These sharp reductions on both sides proved that viscous dampers were quite effective at reducing seismic responses and, therefore, stabilizing and hardening telecommunication towers against earthquakes. Thus, the study validated that in seismic-prone areas, dampers were a valuable addition toward enhancing structural safety and operational continuity.

From time history analysis, the addition of viscous dampers indicates a significant reduction in both X and Y seismic responses. U1: Comparison with U2 shows that displacements were reduced in the X direction by 62%, in comparison with 82% for U2. In the Y direction, reductions on occasion were as high as 81% for U1 and 61% for U2. Such reductions indicate the capability of the dampers to effectively control seismic-induced movements and increase stability and resilience of the tower during earthquakes. Key findings were developed for viscous dampers ensuring effective peak displacement mitigation with increased seismic resilience of the structure, whereas it also guarantees the protection of telecommunication infrastructure in earthquake-prone regions.

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