Deep Science Publishing
https://doi.org/10.70593/978-81-981367-9-4_3

DeepScience
Open Access Books

Chapter 3

Seismic resilience enhancement of telecommunication tower: A linear static analysis with viscous damper

Ashok Meti [1], Swapnil Malipatil [2]

[1,2] *Department of Civil Engineerng, St John College of Engineering and Management, Palghar, Mumbai University, Maharashtra, India.*
[*1] *ashok.meticv011@gmail.com*

Abstract:

Telecommunication towers are always exposed to seismic activity, which jeopardizes essential communication networks both during and after earthquakes. This paper presents an analytical study on the effect of incorporation of viscous dampers on seismic performance of telecommunication towers, keeping linear static analysis into focus. The investigation comprises the evaluation and comparison of base shear, story drift, and story displacement of structures with and without viscous dampers. Generally, base shear-the total horizontal force from seismic action at the base of the tower-is the most important indication of the structural demand. Story displacement and story drift-presently representing the relative movement between two consecutive floors-are studied for determining whether structure flexibility and potential for damage exist. The results show that the addition of viscous dampers effectively reduces story displacement and drift and efficiently dissipates seismic energy while lowering the structure's response. Dampers enhance seismic resilience through the bound deformations and forces that help thereby; therefore, in seismic zones, the towers of telecommunication communication towers operational dependability is extended. This article contributes towards realizing improvement in structures for the telecommunication industry in a safer and more functional condition during earthquakes.

Keywords: viscous dampers, Base shear, story displacement and story drift, seismic zones.

Citation: Meti, A, & Malipatil, S. (2024). Seismic resilience enhancement of telecommunication tower: a linear static analysis with viscous damper. In *Enhancing Seismic Resilience of Telecommunication Towers: Impact of Viscous Damper Integration* (pp. 28-49). Deep Science Publishing. https://doi.org/10.70593/978-81-981367-9-4_3

3.1 Introduction

Generally, telecommunication towers are one of the most crucial infrastructure objects meant to maintain unchanged communication services, above all in seismic hazard areas (Soltanzadeh et al., 2014). There is nothing more inappropriate to discuss the reliability and prompt emergency response than ruined or destroyed communication networks due to such towers in the earthquake area (Soltanzadeh et al., 2014). For that reason, it is necessary to pay attention to increasing seismic resistance of such towers to maintain their operational integrity during strong earth movements (Bazzurro et al.,1994). This paper discusses the possibility of employing viscous dampers to enhance seismic performance, examined by a linear static analysis approach. (Zaman et al., 2012).

Seismic resilience in structural engineering refers to the ability of a structure to withstand and recover from forces of earthquakes without major damage or interruption of service (McNamara et al., 2000). For telecommunication towers, some of the important performance indicators such as base shear, story displacement (Bazzurro et al.,1994), and story drift are very important to bring out information about structural behavior under seismic loading (More et al., 2019). Base shear represents cumulative force at the tower base due to seismic effects (More et al., 2019), and the value indicates a general demand in the structure as a result of seismic forces (Zaman et al., 2012). In general, the high value of base shear reflects the large forces, which may cause critical stresses mainly in taller and flexible structures like telecommunication towers (McNamara et al., 2000). Thus, base shear could be reduced through strategic enhancements, reducing the demand on the whole structure and increasing the resilience of the structure against possible failures (Ramdas et al., 2022). The application of generative artificial intelligence in areas like agriculture and seismic exploration reveals numerous challenges and future research opportunities, highlighting the need for adaptable AI systems in complex environments (Patil et al., 2024; Rane et al., 2024a; Rane et al., 2024b; Rane & Paramesha, 2024; Rane & Shirke, 2024).

Story displacement or the horizontal displacement at each floor or segment of the structure provides an idea of the flexibility and movement capability of the tower (Ras et al., 2016). High displacement can result in nonstructural damage, which may include misalignment of equipment and/or service disruption (Tiwari et al., 2023). In particular, as telecommunication towers rely on perfectly aligned antennas and components(McNamara et al., 2000), specific difficulties can arise from nonstructural damage (Ramdas et al., 2022). Therefore, reducing the story displacement is particularly important to ensure that equipment stored in such structures remains steady and functional (Tiwari et al., 2023).

Another critical parameter is story drift, that is the relative displacement between two consecutive floors or segments in terms of ratio of displacement to story height (Infanti et al., 2008). Story drift is a measure of deformation of the structure and, therefore, it is an indicator of potential inelastic behavior and material strain (Umachagi et al., 2013). High levels of story drift may be associated with plastic deformation and connection failure and, in the extreme (Tiwari et al., 2023), collapse of the structure (Umachagi et al., 2013). Limiting story drift in telecommunication towers is significant not only for maintaining the structural integrity but also for preventing damage to sensitive equipment, ensuring that the tower functions during and after seismic activity (Marko et al., 2004).

Viscous dampers are known to be an effective solution for increasing the structural resilience against seismic forces (Balkanlou et al., 2013). The reduction of forces and deformations transferred to the structure occurs by dissipating seismic energy through fluid movement within the damper (Mathew et al., 2014). This paper investigates how viscous dampers would affect the base shear, story displacement, and the story drift of telecommunication towers (Infanti et al., 2008). Comparisons are made using linear static analysis between damped and undamped structures (Umachagi et al., 2013). The overly simplified linear static model is still valuable for understanding responses of structures and might serve as an initial assessment method to establish the possibility of benefits offered by damping mechanisms (Marko et al., 2004).

3.2 Viscous Dampers

A fluid viscous damper is a device which absorb or dissipates the energy from external excitation by applying resistive force over a finite displacement (Balkanlou et al., 2013). Therefore damper reduces the builted strain energy and response of the structure, merely for resonance condition (Mathew et al., 2014). In other words damper is utilized to resists the response of structure during dynamic response unlike mass and stiffness of structural system (Marko et al., 2004). The stiffness of damper is dependent on several factors such as amplitude of vibration (Infanti et al., 2008), type of construction material and fundamental time period of vibration (Infanti et al., 2008), mode shape and structural components (Infanti et al., 2008).

Dampers are commonly used where:

a) It reduces the storey drifts for high rise buildings.
b) Reduces the unplanned torosional motions of the tall structures.
c) It reduces the large energy dissipation due to earthquake.
d) Reduces the peak displacement of tall building structures.
e) Brief description of the fluid viscous dampers:

Classification of earthquake protective systems.

There are three types of earthquake protective systems such as

1. Passive energy system.
2. Active energy system.
3. **Semi** active system.

Viscous fluid dampers:

A viscous fluid damper is works on the basis of viscous fluid flows through an orifice (Ras et al., 2016), the stainless steel (SS) is move through section that is filled with silicon oil (Ras et al., 2016), and usually the silicon oil is inert (Ras et al., 2016), nontoxic and non flammable & extremely strong for long period of time and the pressure difference b/n two chamber can cause (Marko et al., 2004), silicon oil flows through an orifice in the piston head & earthquake energy is transferred into warm energy (Marko et al., 2004), it dissipate energy into atmosphere (Marko et al., 2004), force to velocity ratio is characterized as F= CxV$^{\alpha}$ (Marko et al., 2004).

Where F – out of force
V- Relative velocity across damper
C- Damping coefficient

And α- exponent constants and its value ranges 0.3 to 1.0 viscous damper can be operating for variable temperature ranges from -40^{0}C to +70^{0}C.

Viscous damper will have unique property and ability to reduce both stress & deflection within the structures subjected to transient the viscous damper varies b/n force within velocity.

Major parts description is as follows, using figure 1. as reference:

1. **Piston rod:** the external end of piston rod is fixed to mounting cleaves and internal end is attached to its piston rod (Soltanzadeh et al., 2014), this piton will reacts with all damping forces and also provides sealing interface with seal (Soltanzadeh et al., 2014), stainless steel is used as piston rod since it can resists the rust on its surface (Soltanzadeh et al., 2014).
2. **Cylinder:** a damper cylinder having fluid medium and it must accept pressure loading during its operation and this type of cylinders generally made with SS steel tubing (Soltanzadeh et al., 2014). These cylinders specially designed for the minimum proof pressure loading equal to 1.5 times the internal pressure under maximum dynamic output (Soltanzadeh et al., 2014).

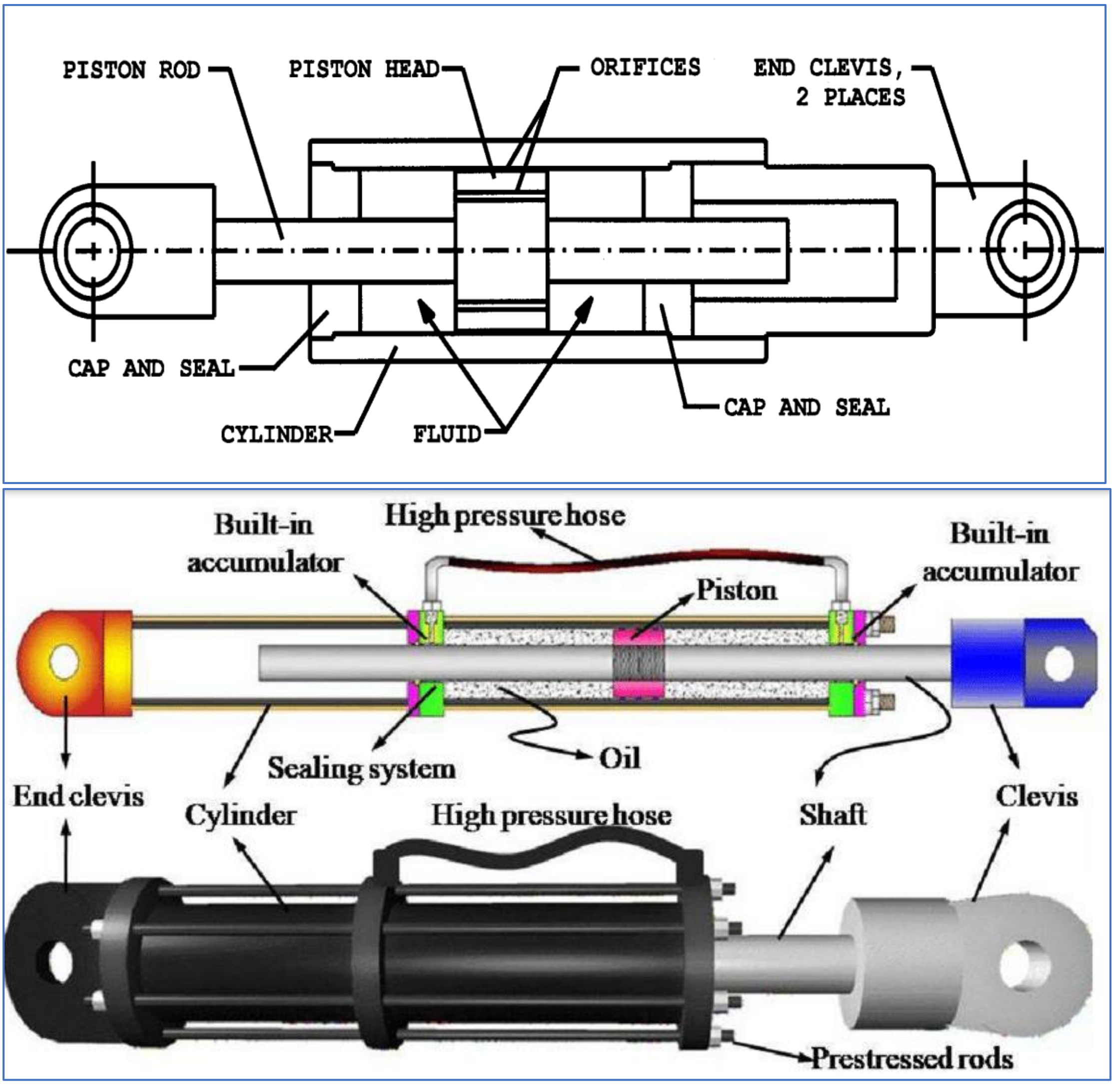


Fig 3.1 Fluid viscous damper arrangement

3. **Fluid:** the dampers are generally used in various applications that require fluid must be fire resistant, nontoxic, and thermally stable and it don't degrade with age (Soltanzadeh et al., 2014). Generally higher flash point silicon is used in such damper (Soltanzadeh et al., 2014).
4. **Seal:** in viscous damper sealing materials such as Teflon, stabilized nylon and acetylene family are generally used (Soltanzadeh et al., 2014).

5. **Piston head:** in the above arrangement piston head is fixed to the piston rod and it separates the two different pressure chambers (Soltanzadeh et al., 2014), the piston rod will help to fluid flows through an orifice and hence it generate the damping force (Soltanzadeh et al., 2014).
6. **Orifices:** the pressurized flow of fluid through piston head is embarrassed by an orifice and in this arrangement damping property ranges b/n 0.3 to 2 (Soltanzadeh et al., 2014). As shown in figure, when tower is subjected to lateral the face on which the lateral force will occurs tension will takes place and on the other side compression will takes place along the shear (Soltanzadeh et al., 2014).

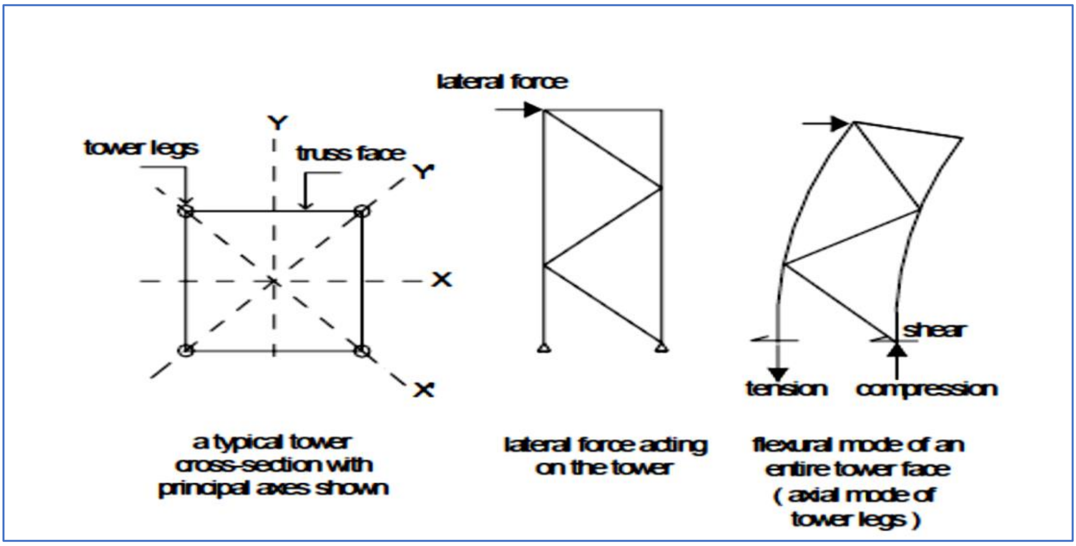


Fig 3.2 Behaviour of tower when subjected to lateral loads

3.3 Objectives of the study.

1. To analyse 4-legged self-supporting telecommunication tower for lateral load analysis particularly for earthquake using equivalent static analysis.
2. Calculate the percentage reduction in base shear by use of viscous dampers.
3. To study the Base shear, top joint displacements are extracted and compared for different seismic zones and soil conditions.
4. To study the effect of use of viscous damper for story drift and displacement for different seismic zones and soil conditions.

3.4 Material property and modelling

This chapter focuses upon developing and validating a structural model, both at linear and non-linear static tools, for the purpose of evaluating chosen mathematical models. To make sure of the accuracy and practicality of this research, basic assumptions and geometric considerations, as seen in this dissertation, together with necessary material parameters, have been incorporated.

The very complex mathematical model captures non-linear behavior in the structural parts. This research uses elastic flexural hinges that integrate plasticity to simulate the parts of frames so as to realistically portray material behavior under stress. This chapter gives an overall overview of the process of the non-linear modelling of framed structures including techniques that have been used to realistically simulate inelastic reactions.

The object of this research work is to investigate the actual life service and the performance of structures for telecommunication towers subjected to seismic loading. A simple design approach is used here with minimal complications to the model in order to have a realistic response from the structure. In this paper, two models of the telecommunication tower- one without a damper are analyzed along with one model with a damper to assess the difference in seismic behavior between them subjected to earthquake loading using SAP 2000 version 18.2.4.

The height is set to 56 meters, with a tapering design with the base set at 10x10 meters and tapering down to 2x2 meters on top. Structural models are prepared with the placement of dampers in one case to create a true comparison of seismic performance and realistic response characteristics of the tower with and without damping.

The material used for construction of tower using Indian standard rolled steel angle section such as ISA-200x200x25mm as used for column legs and ISA-100x100x12mm as used for bracing of tower. The stress stains relationship used as per IS-800-2007, the basic material properties for tower structure as shown in table.

Table 3.2 Comparative values of mode number vs time period

Mode number	**Time period in sec for With Dampers**
1	0.87
2	0.86
3	0.55

4	0.49
5	0.47
6	0.25
7	0.23
8	0.22
9	0.21
10	0.18
11	0.17
12	0.16

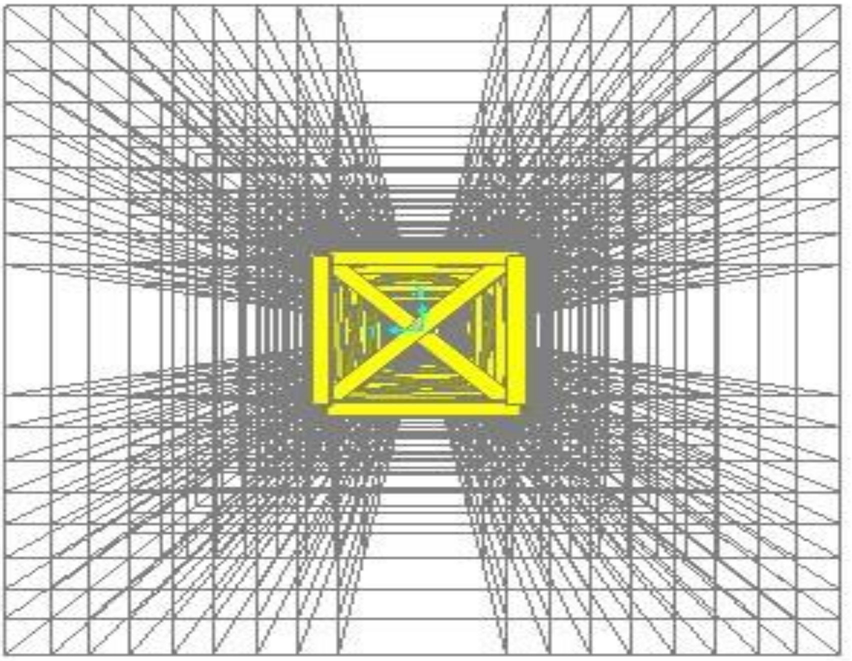


Fig 3.3 Modeling of Telecommunication towers

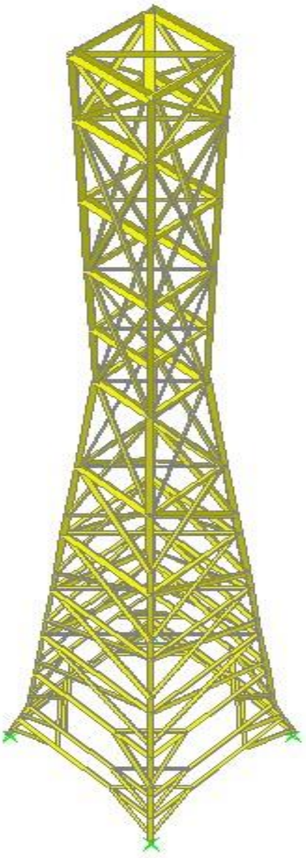
Table 3.1 shows the modal description for telecommunication tower

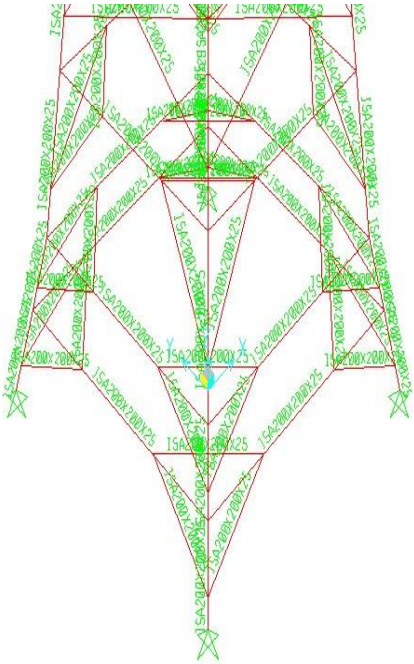
Sl.No	Parameters Used For Modelling	Description Of Tower Model
1.	Plan dimension of model in m	10X10m
2.	Top plan dimension of model in m	2X2m
3.	Height of tower	56m
4.	**Material Property**	
5.	Leg member	ISA-200X200X25mm
6.	Bracing member	ISA-100X100X12mm
7.	Bracing type	Concentric and eccentric
8.	Types of soil	Hard, medium & soft soil
9.	Seismic zones	II, III, IV & V
10.	Response spectrum (R)	4
11.	Importance factor (I)	1
12.	Grade of steel	Fe-345 Hot ruled steel section
13.	Plat form load on tower (kN/m^2)	1
14.	Stiffness of damper (kN/m)	1645

Antennas Loading On Towers

Sl. no	Item	Quantity	Diameter (m)	Weight (kg)
1.	CDMA	8	0.26X2.5	20
2.	Microwave	2	1.2	77
3.	Microwave	3	0.6	45
4.	Microwave	4	0.3	25

Total joint load consisted on telecommunication tower is 50kN





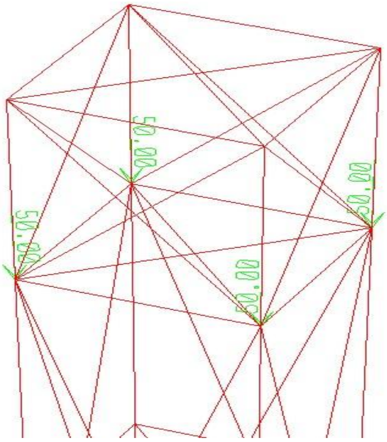


Fig 3.4 Details of section used in tower

Fig 3.5 Details of loading

3.5 Results and Discussion

The following table gives the time periods of different vibration modes of a structure with damped dampers. Time period is that period of time through which each cycle of vibration lasts. The time period increases as the mode number rises, meaning higher mode numbers relate to higher-frequency vibrations, which relate to shorter time periods. The result shows that with the rising mode number, the time period generally tends to reduce in nature, which is common in the structure designed by dynamic analysis. Lower modes (as Mode 1) typically occur over longer time periods since they describe the fundamental or primary vibration of the structure, usually involving larger, slower motion. Higher modes, however are higher-frequency oscillations involving quicker, smaller motion of structural components as reflected in modes 6–12 that have time periods much shorter than the time periods for the lower modes. Presumably the dampers would help to control and reduce these time periods in higher modes, providing stability and minimum amplitude due to vibration in response to external forces such as earthquakes or wind.

The table provides the frequencies for various modes of vibration of a damped structure in units of Hz, cycles per second. A general trend appears where the frequency increases with the rise in mode number. Lower mode frequencies, for instance, Mode 1 and Mode 2, at 1.16 Hz are typically the fundamental oscillations of the overall structure, consisting of larger, more global deformations. These modes are important toward understanding the dynamic behavior of the structure at its basic regime. As mode numbers increase, the frequencies are higher; hence, they reflect quicker, local vibrations in the structure. The increase from lower to higher frequencies with higher modes, up to 6.29 Hz at Mode 12, is typical in a dynamic analysis of structures. Installation of dampers is a natural occurrence with such a frequency distribution, damping overzealous oscillations at lower modes and thus improving structural stability under all forms of vibrations. This controlled range of frequency points towards an effective damped system, thus reducing the resonance effects and providing structural resilience against dynamic forces.

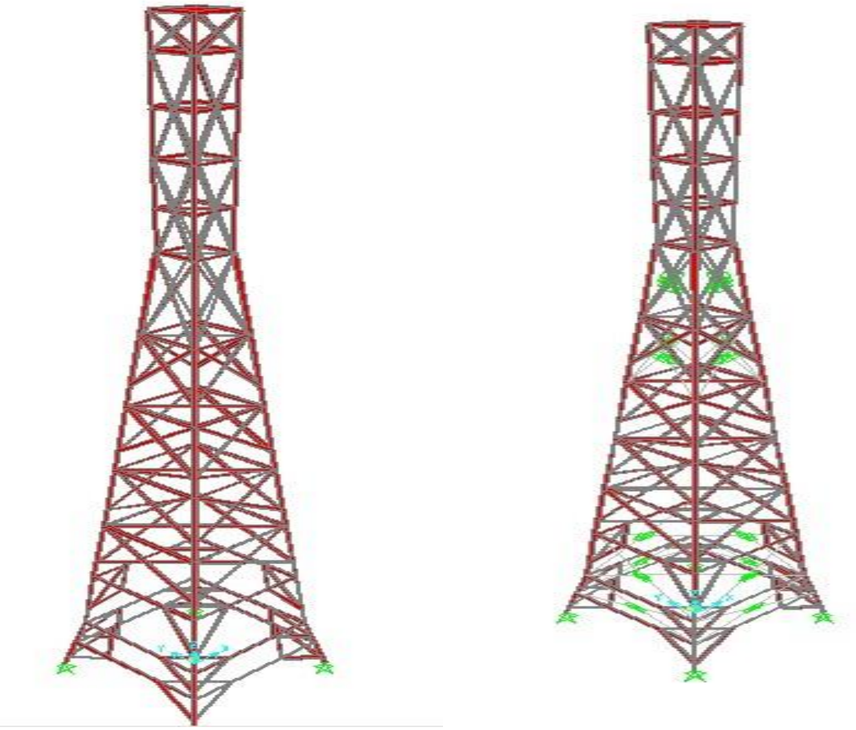


Fig. 3.6 Telecommunication Tower with and without Dampers

The results are presented as a table below that shows the value of base shear for various soil types with dampers. A base shear value is defined as the extreme lateral force at the base of the structure caused by seismic or other dynamic loads. Evidence from these results suggests that an increase in soil flexibility from hard to soft soil increases base shear.

The smallest base shear value is presented by Type I or Hard Soil with the result of 20.77 kN. This kind of soil offers the most stable foundation and the least amplification of the seismic force.

Medium Soil Type II exhibited a slight rise in base shear to 28.25 kN as the soil was more flexible, which enables it to move out further during dynamic loading.

One of the soils is soft soil Type III, with the maximum value of base shear. The reason is that soft soil has a higher deformability tendency to amplify seismic forces through which more force is exerted on the structure.

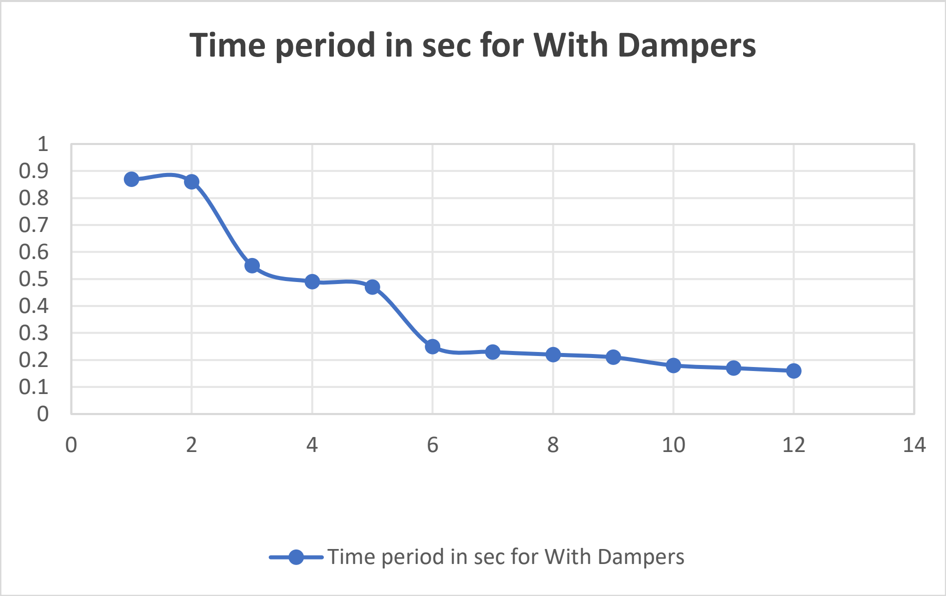


Table 3.3 Comparative values for mode number vs frequency

Mode number	Frequency (Cyc/Sec.for With Dampers
1	1.16
2	1.16
3	1.82
4	2.05
5	2.12
6	3.96
7	4.35
8	4.45
9	4.70
10	5.67
11	5.90
12	6.29

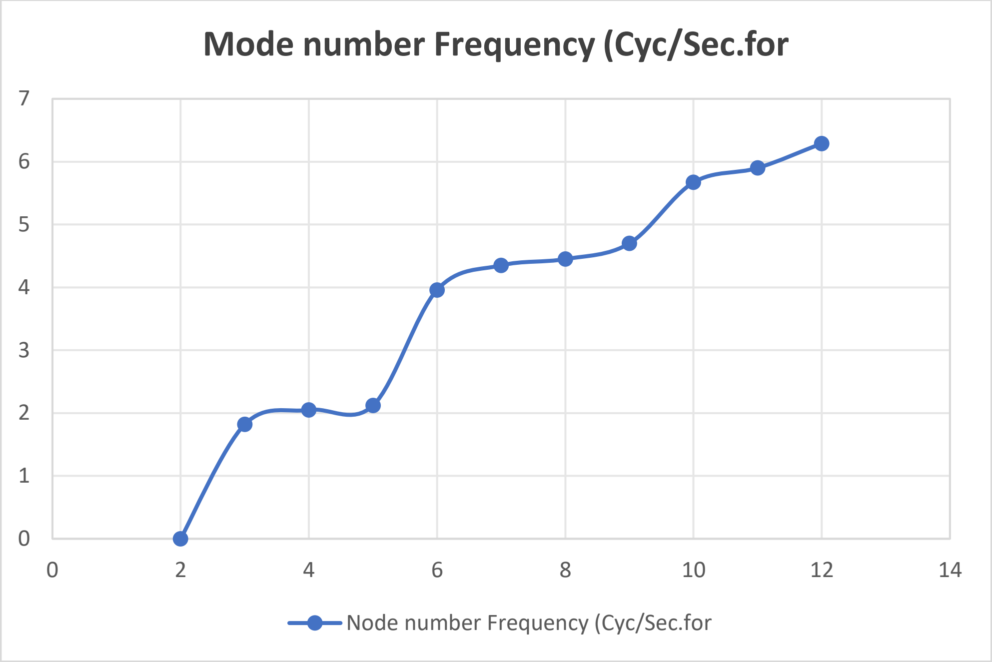
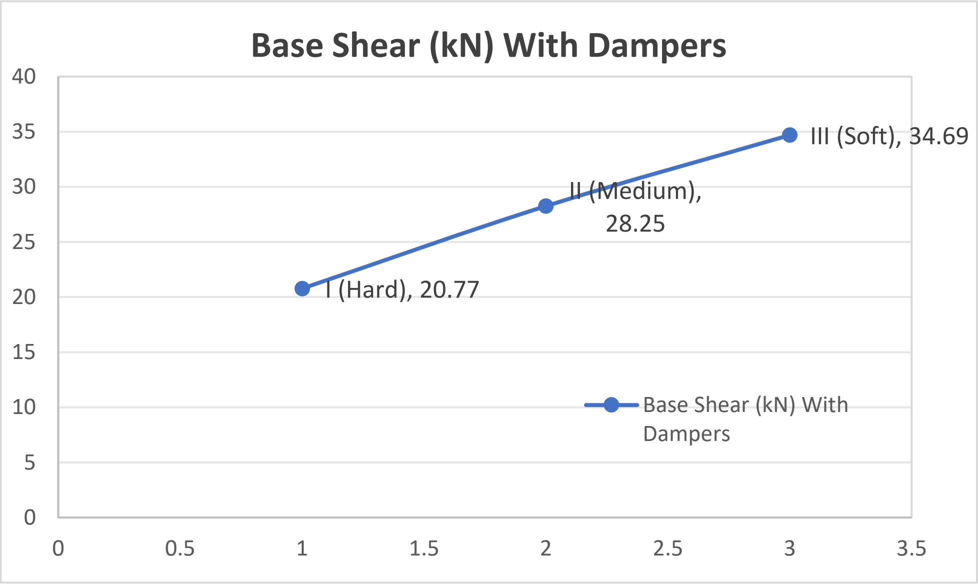


Table 3.4 Base shear values for different soil conditions

Soil Type	**Base Shear (kN)** **With Dampers**
I (Hard)	20.77
II (Medium)	28.25
III (Soft)	34.69



This pattern draws attention to the effect of soil conditions on structural response under dynamic loads. In that way, the dampers tend to manage the forces but cannot fully offset the increased demands placed on structures by softer soils as these are naturally more prone to transmit greater force because of their flexibility and amplification effects.

Table 3.5 Displacement values for different soil types

Soil Type	**Displacement (mm) With Dampers**
I (Hard)	13.57
II (Medium)	18.46
III (Soft)	22.66

Table highlights the displacement values for different soil types with dampers installed, measured in millimeters. Displacement is understood to be the lateral movement of the structure under dynamic loads such as seismic forces. The displacements increase when the soil type is softer, which is consistent with the effect of soil stiffness to the behavior of the structure. Type I soil is hard soil that displaces the least. This is because it creates a more rigid base, hence there is minimal movement of the structure during dynamic loading. Medium soil of Type II has a displacement of about 18.46 mm because it is relatively flexible; the structure can move more under seismic or other forces. The maximum structural displacement is obtained when it is subjected to type III soft soil, which stands at 22.66 mm. This is because soft soils are very deformable, and thus they amplify the vibration, causing more structural movement. These results indicate that those softer soils increase displacement even with dampers, since the soil reduces to some extent its capability to absorb and distribute seismic forces. Dampers help check but cannot totally eliminate larger displacements caused by soil's inherent flexibility.

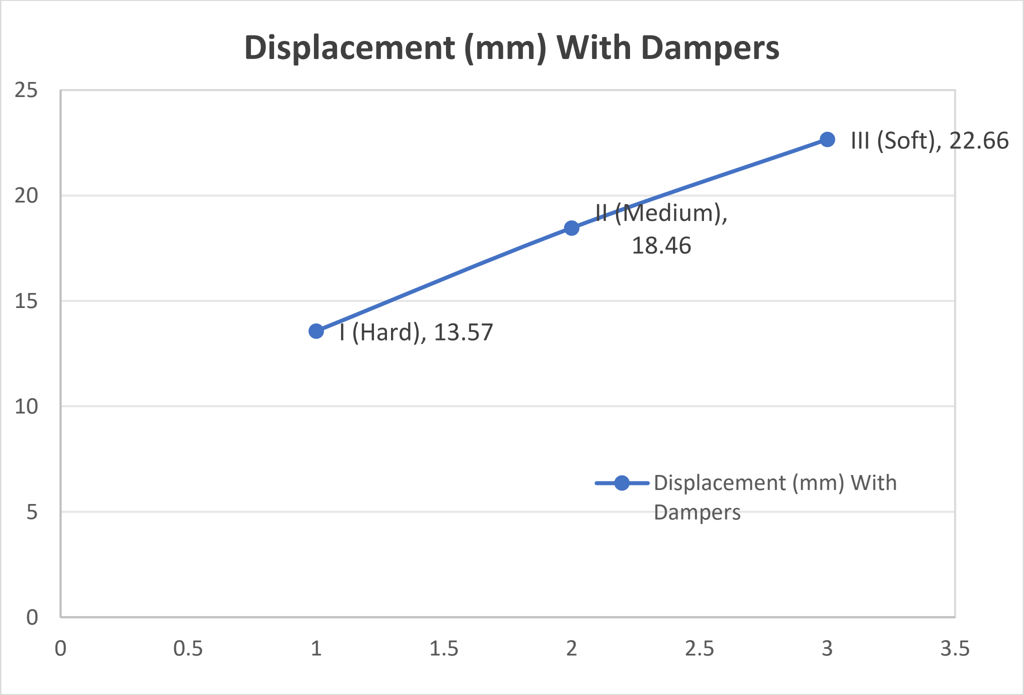
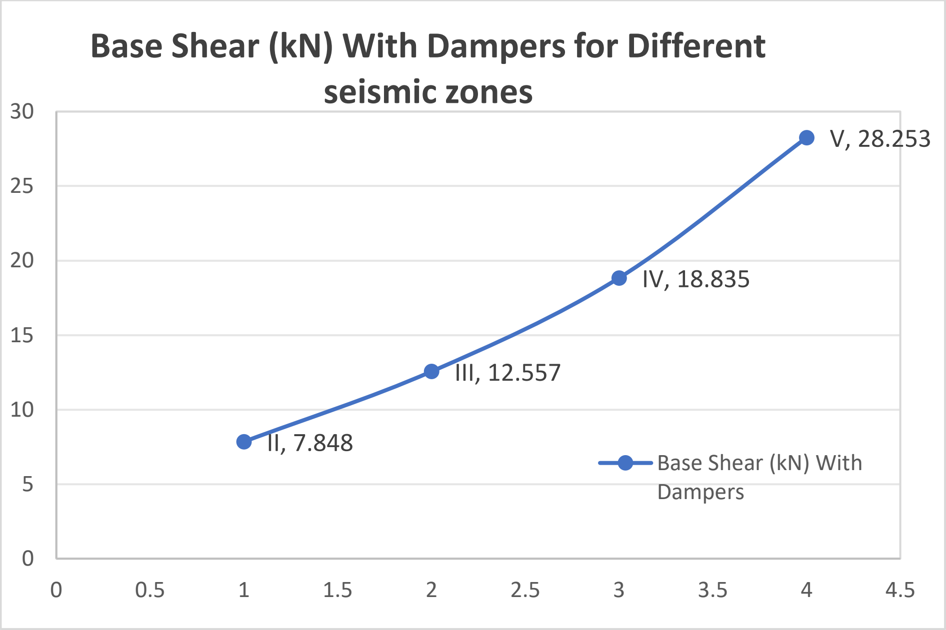


Table 3.6 Base shear for different zones

Seismic Zones	Base Shear (kN) With Dampers
II	7.848
III	12.557
IV	18.835
V	28.253

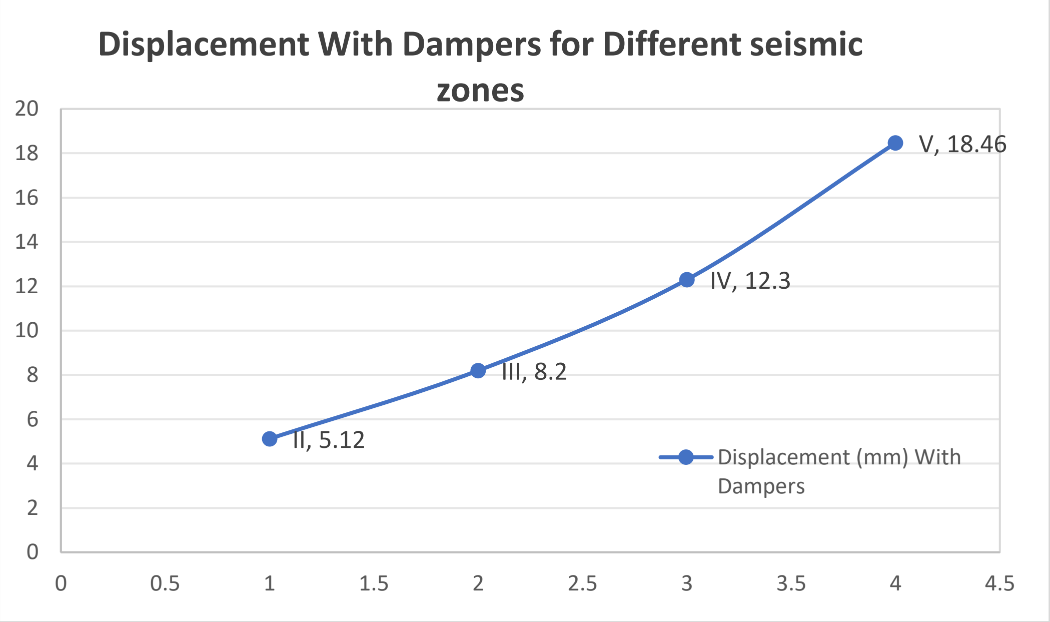


The table gives the base shear values obtained after the inclusion of dampers for diverse seismic zones. The base shear is that lateral force applied at the base of a structure during earthquakes and has magnitudes greater as the number of seismic zone is greater. The minimum amount of base shear is the 7.848 kN recorded in Zone II, known as the least seismicity. This is because the probability and intensity of seismic activity are lesser and therefore less lateral forces are applied on the structure. Zone III shows a rise in base shear (12.557 kN), which indicates moderate seismic risk with correspondingly higher forces. Zone IV shows even greater base shear compared to Zone III (18.835 kN) and reveals high seismic risk with stronger force effects on the structures. Zone V-This is the highest seismicity zone showing the maximum base shear of 28.253 kN because of the high probability of critical seismic events, which produce the strongest forces. These values indicate that as the level of seismic zones increases, so too do the base shears. While the dampers manage the forces, the growing base shear indicates that higher structural demands are associated with higher seismic activity.

Table 3.7 Displacement values for different zones

Seismic Zones	**Displacement (mm)** **With Dampers**
II	5.12
III	8.20
IV	12.30
V	18.46

A table is constructed that shows the displacement values for different zones with dampers. Displacement is the measurement of lateral movement of a structure under seismic forces, and therefore displacement is larger in higher seismic zones. Zone II presents the lowest value of displacement, that is 5.12 mm, due to the fact that low seismic activity would result in minimal movement of the structure. Zone III has a moderate displacement (8.20 mm) due to increased seismic intensity, which generates higher lateral movement. Zone IV The second highest is zone IV, which would give a higher value of displacement at 12.30 mm, considering the higher seismic forces and impact on the structure.



Zone V, which is the zone of maximum seismicity, covers the largest size of displacement 18.46 mm because it is under the highest forces of seismic, therefore it experiences the highest structural movement. This clearly shows that displacement increases with an increase in the zone of seismicity, even when dampers are included. The dampers do modify the movement in case there is some action; nonetheless, the greater displacements seen in larger seismic zones correspond to the higher ground motion and energy transfer.

3.6 Conclusions

The details the time periods for the first twelve modes of vibration of a telecommunication tower with viscous dampers. Results are presented to have the time period longest for the initial mode at 0.87 seconds which indicates that the response of the tower is related to a lower frequency and larger amplitude motion when subjected to seismic loading. The time periods continually decreased with the twelfth mode having the smallest time period: 0.16 seconds. This trend indicates that for higher modes, and thus increased frequency and decreased amplitude of vibrations, deformations in structures actually have characteristics of localized rather than overall structural movement.

From the relationship of soil-type sensitivity with seismic demand for a telecommunication tower with the viscous dampers considered, as base shear increases rapidly from 20.77 kN with hard to soft soils when stiffness was decreased from hard (Type I) to soft soil (Type III). As a result, towers will face high seismic forces and are characterized by amplified ground motion due to softer soil. The results here work well to stress the role of soil conditions in seismic design and indicate that although viscous dampers may mitigate the seismic response, towers on softer soils warrant further evaluation for sufficient resilience to increased base shear forces.

Values for displacement show that soil type plays a significant role in the lateral movement of the telecommunication tower even with dampers introduced into the structure. The displacements increase from 13.57 mm for hard soil Type I to 22.66 mm for soft soil Type III, which reveals greater flexibility in the structure and greater movement in softer soils. These present that though viscous dampers are installed to reduce the displacement of towers, larger movements will be encountered at towers located on softer soils, and thus, a need for further design works to provide stability and with a minimum disturbance to equipment during earthquakes. Base shear values clearly show a relationship between seismic zone intensity and the seismic force induced on the telecommunication tower even with dampers in place. With an increase in the seismic zone level from II to V, the base shear values increase markedly from 7.848 kN to 28.253 kN. This signifies greater urgency for increased structural resilience at higher seismic zones. Thus, these results highlight the need for advanced seismic design measures, especially at high-risk locations, to ensure the stability and operational reliability of a tower in light of increasing seismic forces.

References

Balkanlou, V. S., Karimi, M. R. B., Azar, B. B., & Behravesh, A. (2013). Evaluating effects of viscous dampers on optimizing seismic behavior of structures. *International Journal of Current Engineering and Technology*, *3*(4), 1150-1157.

Bazzurro, P., & Cornell, C. A. (1994). Seismic hazard analysis of nonlinear structures. I: Methodology. *Journal of Structural Engineering*, *120*(11), 3320-3344.

I.S. 5613: Part 2: Sec: 1: 1989: Code of Practice for Design, Installation and Maintenance for Over Head Power Lines: Lines above 11 KV And Up to And

I.S. 5613: Part 2: Sec: 2: 1989: Code of Practice for Design, Installation and Maintenance for Over Head Power Lines: Lines above 11 KV And Up to And Including 220 KV: Installation and Maintenance.

I.S. 802: Part 1: Sec: 1:1995: "Code of Practice for Use of Structural Steel in Over Head Transmission Line Towers-Materials and Loads.

I.S. 802: Part 2: Sec: 1:1995: "Code of Practice for Use of Structural Steel in Over Head Transmission Line Towers-Permissible Stresses.

I.S. 875: Part 3: 1987: Code of Practice for Design Loads (other than Earthquake) for Buildings and Structures: Wind loads

Infanti, S., Robinson, J., & Smith, R. (2008, October). Viscous dampers for high-rise buildings. In *The 14th World Conference on Earthquake Engineering*. Beijing: China.

IS: 1890-2002 (Part-1), "Indian standard Criteria for Earthquake Resistant Design of Structures", Part-1: General Provisions and Buildings, Bureau of Indian Standard. New Delhi.

IS: 875-1987 Part-2,"Code of Practice for Design Loads (Other than Earthquake)"for Buildings and Structures: Part-2, Imposed Loads. Bureau of Indian standards, New Delhi.

Marko, J., Thambiratnam, D., & Perera, N. (2004). Influence of damping systems on building structures subject to seismic effects. *Engineering Structures*, *26*(13), 1939-1956.

Mathew, L., & Prabha, C. (2014). Effect of fluid viscous dampers in multi-storeyed buildings. *Impact Int. J. Res. Eng. Technol.(IMPACT IJRET)*, *2*(9), 59-64.

McNamara, R. J., Huang, C. D., & Wan, V. (2000). Viscous-damper with motion amplification device for high rise building applications. In *Advanced Technology in Structural Engineering* (pp. 1-10).

More, V., Patil, V., & Takkalaki, S. (2019). Dynamic analysis of RCC frame structures with and without viscous damper having different aspect ratio. *IJISET-International Journal of Innovative Science, Engineering & Technology*, *6*(10).

Patil, D., Rane, N. L., Desai, P., & Rane, J. (2024). Machine learning and deep learning: Methods, techniques, applications, challenges, and future research opportunities. In Trustworthy Artificial Intelligence in Industry and Society (pp. 28-81). Deep Science Publishing. https://doi.org/10.70593/978-81-981367-4-9_2

Rane, J., Kaya, O., Mallick, S. K., & Rane, N. L. (2024a). Artificial intelligence in education: A SWOT analysis of ChatGPT and its implications for practice and research. In Generative Artificial Intelligence in Agriculture, Education, and Business (pp. 142-161). Deep Science Publishing. https://doi.org/10.70593/978-81-981271-7-4_4

Rane, J., Kaya, O., Mallick, S. K., & Rane, N. L. (2024b). Smart farming using artificial intelligence, machine learning, deep learning, and ChatGPT: Applications, opportunities, challenges, and future directions. In Generative Artificial Intelligence in Agriculture, Education, and Business (pp. 218-272). Deep Science Publishing. https://doi.org/10.70593/978-81-981271-7-4_6

Rane, N. L., & Paramesha, M. (2024). Explainable Artificial Intelligence (XAI) as a foundation for trustworthy artificial intelligence. In Trustworthy Artificial Intelligence in Industry and Society (pp. 1-27). Deep Science Publishing. https://doi.org/10.70593/978-81-981367-4-9_1

Rane, N. L., & Shirke S. (2024). Digital twin for healthcare, finance, agriculture, retail, manufacturing, energy, and transportation industry 4.0, 5.0, and society 5.0. In Artificial Intelligence and Industry in Society 5.0 (pp. 50-66). Deep Science Publishing. https://doi.org/10.70593/978-81-981271-1-2_3

Ramdas, L. M., Santhi, M. H., & Malathi, G. (2022). A study on high-rise RC structure with fluid viscous damper using python. *Research on Engineering Structures and Materials. Research Article*, *362*, 1101.

Ras, A., & Boumechra, N. (2016). Seismic energy dissipation study of linear fluid viscous dampers in steel structure design. *Alexandria Engineering Journal*, *55*(3), 2821-2832.

Soltanzadeh, G., Shad, H., Vafaei, M., & Adnan, A. (2014). Seismic performance of 4-legged Self-supporting Telecommunication Towers. *Int. Journal of Applied Sciences and Engineering Research*, *3*(2).

Tiwari, P., Badal, P., & Suwal, R. (2023). Effectiveness of fluid viscous dampers in the seismic performance enhancement of RC buildings. *Asian Journal of Civil Engineering*, *24*(1), 309-318.

Umachagi, V., Venkataramana, K., Reddy, G. R., & Verma, R. (2013). Applications of dampers for vibration control of structures: an overview. *Int. J. Res. Eng. Technol*, *2*(13), 6-11.

Zaman, S., Ornthammarath, T., & Warnitchai, P. (2012, September). Probabilistic seismic hazard maps for Pakistan. In *15th world conference on earthquake engineering, Lisbon, Portugal*.