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Chapter 2

Enhancing seismic resilience of telecommunication tower: By linear static approach for without viscous damper

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Abstract: While telecommunication towers are crucial components of modern telecommunication networks, their capability to withstand seismic loading is still a major issue, especially in earthquake-prone areas. Traditional seismic performance enhancement methods usually aim at the use of viscous dampers to dissipate ground motions. Nevertheless, the installation and maintenance of such dampers can be arduous and thus, expensive procedures. A linear static analysis allows the use of alternate strategies for the seismic resilience of towers that includes increases in structural stiffness, bracing systems, or mass modification of towers instead of providing additional energy dissipation motors. Emphasis will be placed on structural modification of the system - such as bracing, mass distribution, and base reinforcement optimization - which will lead to the identification of low-cost measure solutions for improved tower stability under seismic loads. The linear static method is deployed to model these modifications and to carry out the assessment of their ability to improve the towers' movement reduction and tension of the internal parts. According to the simulations, these non-damper-based reinforcement methods are reliable means to ensure better seismic performance even for a specified geometry of a certain tower. These breakthroughs have practical applications in cost-saving eco-friendly seismic reinforcement of telecommunication towers, which ensures a safer and more resilient infrastructure.

Keywords: linear static analysis, structural stiffness, bracing systems, or mass modification, Base shear, story displacement and story drift.

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2.1 Introduction

Telecommunication towers are a vital piece of today's infrastructure. They are the structural backbone of everyday networks and alternative routes for emergency communication (Sarwar et al., 2016). These towers are sited in diverse environments, including different seismic zones (Sarwar et al., 2011), and so they experience a wide range of loading with seismic forces being among the most significant (Sarwar et al., 2011). Due to their slender form and vertical structure (Atkinson et al., 2004), telecommunication towers are structurally sensitive to lateral loads, whereby the lateral sway of the tower may cause excessive displacements (Atkinson et al., 2004), structural damage, or even complete collapse during seismic events (Atkinson et al., 2004). First, it is imperative to ensure the seismic resilience of the structures in the key facilities, thereby preventing breaks in the communication system and safeguarding the investments and infrastructure (Hassan et al., 2023). Artificial intelligence methodologies are increasingly being used to optimize seismic data processing, enhancing predictive accuracy and operational efficiency (Patil et al., 2024; Rane et al., 2024a; Rane et al., 2024b; Rane & Paramesha, 2024; Rane & Shirke, 2024).

This study proposes a linear static approach to improving the seismic resilience of telecommunication towers without the use of viscous dampers (Hassan et al., 2023). The linear static analysis method provides a simplified approach for evaluating seismic effects by assuming elastic structural behavior and focusing on the most critical loading scenarios (Khalid et al., 2021). Although linear static analysis is generally conservative and less detailed than nonlinear dynamic methods (Khalid et al., 2021), it offers valuable insights into basic load-bearing and displacement characteristics (Khalid et al., 2021), making it an effective tool for preliminary design and reinforcement strategy evaluation (Khalid et al., 2021).

In this research, we focus on structural adjustments to enhance the seismic performance of telecommunication towers (Alam et al., 2020). Specifically, we explore the use of optimized bracing patterns, mass redistribution (Alam et al., 2020), and structural adjustments to control critical factors such as base shear, story drift, and overall displacement under seismic loading (Bhaskararao et al., 2006). Each of these factors plays a significant role in the seismic response of towers (Bhaskararao et al., 2006). The Linear Static (Equivalent Static) Analysis is the main method of this study, which is used to assess the seismic performance of telecommunication towers (Shah et al., 2021). Linear Static Analysis is a simpler method that assumes linear elastic behavior and thus is appropriate for the preliminary design stages or for the geometrically regular structures when the detailed dynamic analysis may be way more unnecessary (Mevada et al., 2012). The forces, caused by earthquakes, are assumed to be a single lateral load that will be equivalent to the seismic demand at the highest point of the structure in this method (Lavan et al., 2006). This equivalent load is calculated using the following factors, namely (Shah et al., 2021), the seismic weight of the structure, local ground acceleration, and structural characteristics (Mevada et al., 2012), thus it becomes an easy matter to apply the tool for the evaluation of how well the structure can endure an earthquake (Lavan et al., 2006).

The Equivalent Static Analysis method gives a very conservative estimate of the maximum forces and displacements which the tower can possibly be loaded with during an earthquake (Lin et al., 2002). Dynamic loading is not time-dependent, nevertheless (Narkhede et al., 2014), it allows us to gain some crucial information connected with the performance, e.g., the base shear (Lavan et al., 2006), story drift, and overall displacement (Lavan et al., 2006), which are key factors in structural safety (Lavan et al., 2006). It is the most suitable method for cell towers (Mevada et al., 2012), which tend to be quite regular and predictable in their structure, hence it is easier to model and assess them (Mevada et al., 2012).

Telecommunication towers usually remain high, thin, and their body is supporting each of the structural members (Ras et al., 2016). These towers too are in areas with very high seismic tremors (Ras et al., 2016). Their geometry and foundation properties make them prone to lateral loads caused by seismic events that lead to large structural displacements, member stresses (Castellano et al., 2012), and even ultimate failure if not correctly designed (Castellano et al., 2012). SAP2000 comes with features that are perfect for seismic issues (Mevada et al., 2012). The program along with static and dynamic analysis capability is possible with SAP2000 which gives engineers an opportunity to simulate earthquakes affecting towers and as a result (Mevada et al., 2012). designers can reinforce the towers accordingly (Mevada et al., 2012).

A popular feature that SAP2000 offers is the effective reinterpretation of the analyzed data and thus the reporting of guiding engineers in the towers in detecting the elements that may need to be reinforced (Castellano et al., 2012). The engineers have the opportunity to monitor towers behavior in case a group of parameters is considered (displacement, the base shear, axial forces, bending moments) (Castellano et al., 2012). With this, the engineers can modify the structural configuration, cross-section sizes, or materials used to improve seismic performance effectively (Ras et al., 2016).

2.2 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 (Domenico et al., 2019). To make sure of the accuracy and practicality of this research

(Pineda et al., 2019), basic assumptions and geometric considerations, as seen in this dissertation, together with necessary material parameters, have been incorporated (Pineda et al., 2019).

The very complex mathematical model captures non-linear behavior in the structural parts (Ras et al., 2016). This research uses elastic flexural hinges that integrate plasticity to simulate the parts of frames so as to realistically portray material behavior under stress(Castellano et al., 2012). 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(Castellano et al., 2012).

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(Ras et al., 2016). A simple design approach is used here with minimal complications to the model in order to have a realistic response from the structure(Mevada et al., 2012). 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(Mevada et al., 2012).

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 (Ras et al., 2016). 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 (Ras et al., 2016).

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 (Alam et al., 2020). The stress stains relationship used as per IS-800-2007, the basic material properties for tower structure as shown in table (Shah et al., 2021).

Table 2.1 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

All these elements are designed in such a way that loads are distributed quite evenly throughout the tower structure, thus making it safe and stable. In the tower figure normally, the base, the middle sections, and the top are involved and supported by bracing elements that have been made with objectives of nullifying bending and buckling effects due to different types of loads.

Table 2.2 Base shear values for different soil conditions

Soil Type	Base Shear (kN) for Without Dampers
I (Hard)	20.36
II (Medium)	27.69

III (Soft)	34.00

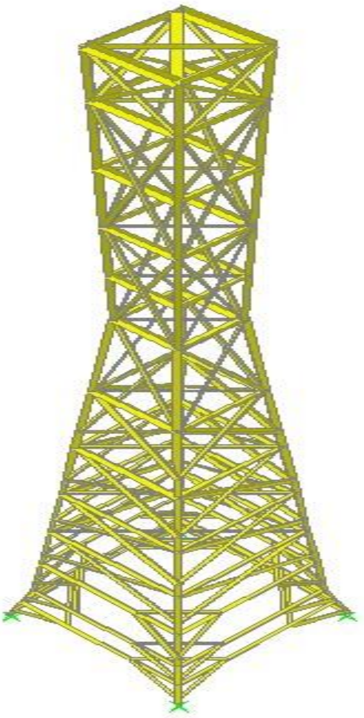


Fig 2.1 The plans of render view of the tower.

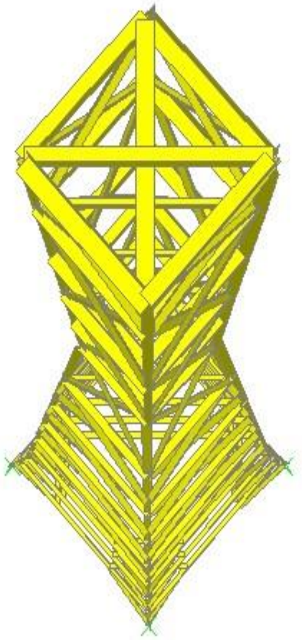


Fig 2.2 Elevation of tower.

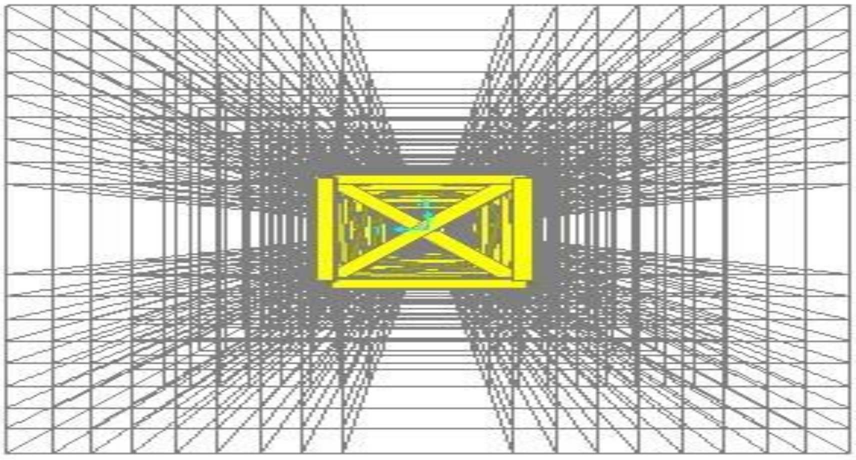


Fig 2.3 Grid lines showing in the model.

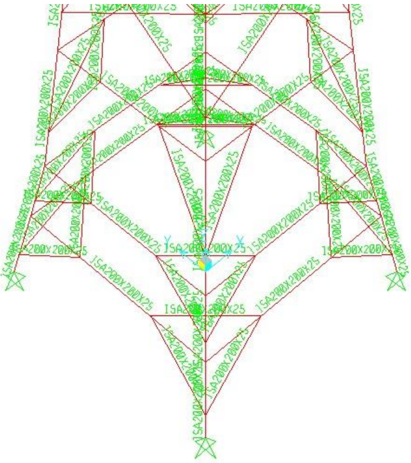


Fig 2.4 Details of section used in tower

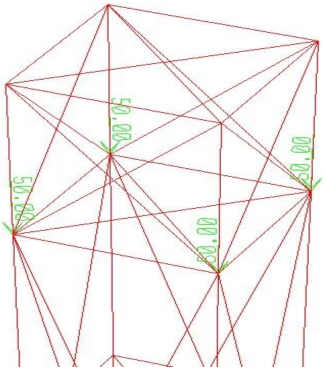


Fig 2.5 Details of loading

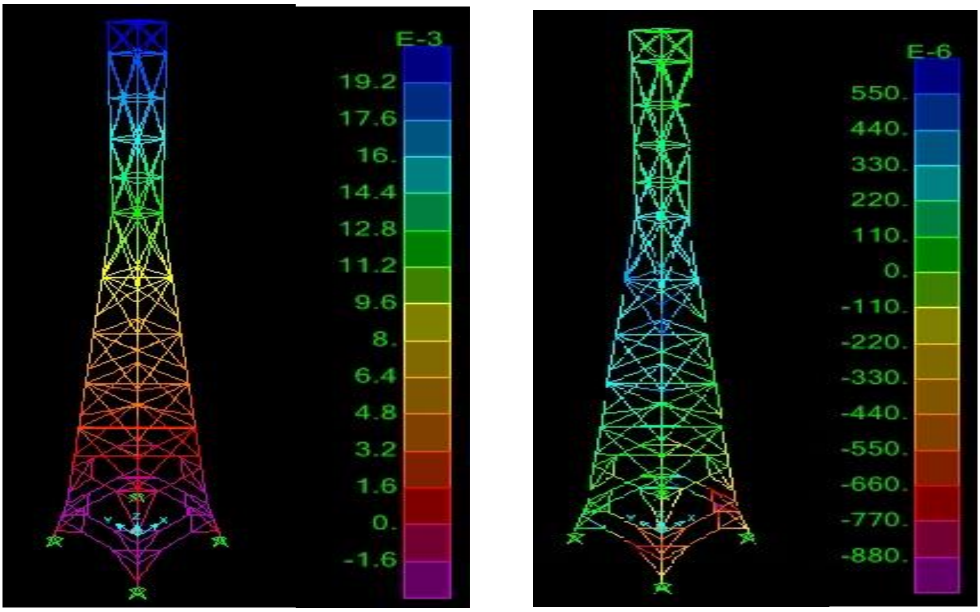
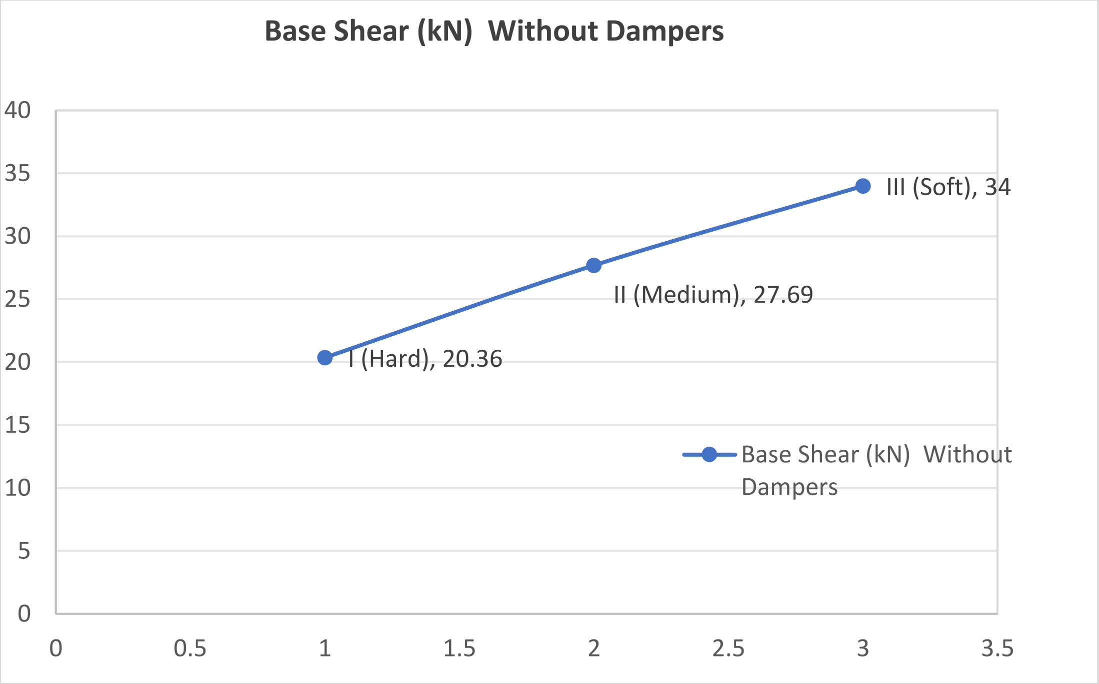


Fig.2.6 Deformed shapes for static load analysis for with and without damper

2.3 Results and Discussion



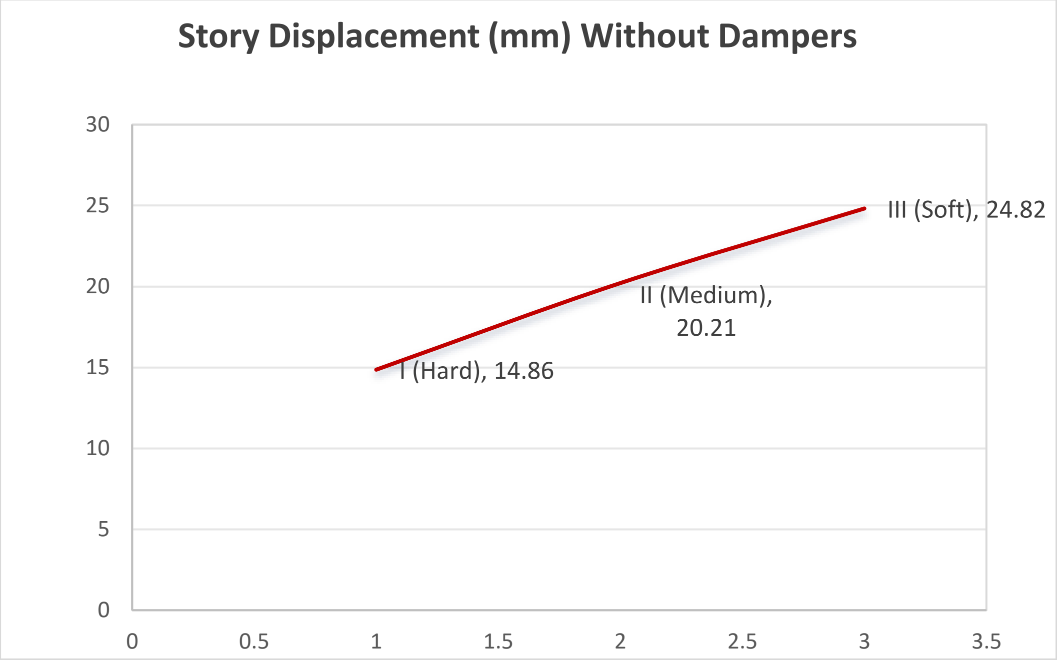
Hard Soil (I) hence gives considerable support with less ground motion amplification, such that the base shear values are only minimum to stand at 20.36 kN.

For Medium Soil (II), a medium ground motion is provided, and there is therefore an increase in base shear value up to 27.69 kN.

The lowest stiffness from all such soils was experienced by Soft Soil (III), with the most amplification of seismic forces, the highest being for base shear at 34.00 kN.

Table 2.3 Displacement values for different soil types

Soil Type	**Story Displacement (mm) For Without Dampers**
I (Hard)	14.86
II (Medium)	20.21
III (Soft)	24.82



Hard Soil (I) is that one that supports a good structure together with stability and hence displaces very negligible to the extent of 14.86 mm, as ground motion amplification is very nominal. Medium Soil (II) lies in the middle group that exhibits some level of elasticity as well as permitting some higher level of displacement at 20.21 mm. Soft soil (III), the most flexible of all, amplifies seismic motion and thus gives rise to the maximum displacement, 24.82 mm.

2.4 Conclusion

From the above results we observed that the base shear increases from hard to soft soil types, agrees with what should happen for a structure under seismic loading. Seismic waves are amplified in soft soils, resulting in higher base shear forces on the telecommunication tower. This exemplifies why soil-structure interaction is very important in seismic analysis since the type of soil indeed influences the seismic response and the force that the structure has to counteract. Therefore, because of the softer soils, seismic design for towers may require more considerations, such as the use of dampers or reinforced foundations, to ensure stability and resilience of the tower under shaking conditions.

In all three types of soils-hard, medium, and soft soils-it varies at 14.86 mm for hard soil, 20.21 mm for medium soil, and 24.82 mm for soft soil-and agrees with expectations from principles on soil-structure interaction. Soft soils tend to amplify seismic waves and result in higher forces on the tower and subsequently more significant lateral displacements. Harder soils do not allow the wave to be amplified, resulting in less displacement. This makes the point of taking into consideration soil types while doing seismic analysis since conditions of the soil play a significant role in the response to structures due to seismic especially in cases of telecommunication towers which ought to remain stable during seismic activity.

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