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Impact of Earthquake and Wind Force on the Structural Behavior of Monopole and Self Supporting Tower

Parikshit Jawanjal[1], Dr. Suchita Hirde[2]

[1]*M.Tech Student (Structural Engineering) at Government College of Engineering, Amravati, Maharashtra*
[2] *Professor & HOD of Applied Mechanics at Government College of Engineering, Amravati, Maharashtra*

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Abstract - Telecommunication towers are essential infrastructural elements that support the functioning of modern communication systems, including mobile networks, television broadcasting, and emergency communication services. With the increasing reliance on high-speed connectivity and the expansion of 5G technologies, the need for structurally efficient and resilient tower designs has become more critical than ever, especially in urban and seismically active areas. This study presents a comparative analysis of three types of telecommunication towers, Self-Supporting Towers, Monopoles, and Cable-Supported Monopoles with an emphasis on their performance under wind loads and seismic conditions. Advanced modeling and analysis were carried out using STAAD Pro software, employing both gust wind load calculations and non-linear time history analysis for seismic behavior simulation. The parameters considered include lateral displacement, natural frequency, time period, and acceleration response under dynamic loading. The results demonstrate that while monopoles are more space-efficient and show better performance than traditional self-supporting towers, the inclusion of cable support significantly enhances the structural behavior of monopoles. The Cable-Supported Monopole not only reduces displacement but also exhibits better stability under dynamic conditions, making it a more resilient and structurally sound choice, especially in locations with space constraints and higher seismic risks. This study contributes to the ongoing research in telecommunication infrastructure by offering insights into optimized tower selection and design practices for improved structural safety and performance.

Key Words: Self-Supporting Towers, Monopoles, Time History Analysis, STAAD Pro.

1. INTRODUCTION

In the present age, telecommunication towers are a critical component of communication infrastructure, ensuring the smooth transfer of information across vast distances. Their importance becomes even more significant during natural disasters like earthquakes, floods, or cyclones, where real-time communication is essential for coordinating emergency responses. These towers also support key services such as television broadcasting, radio transmission, military communication, and the operation of essential utilities like electricity, gas, and fuel systems.

Structurally, telecommunication towers are categorized into three main types: self-supporting towers, guyed towers, and monopoles. Self-supporting towers are either 3-legged or 4-legged truss systems that stand independently and are commonly used due to their high strength and small base area requirement. Guyed towers use tensioned cables for stability and are suitable for open spaces due to their large footprint. Monopoles are compact, sleek poles used mostly in urban or space-constrained areas. While early designs focused mainly on resisting wind loads, past failures during earthquakes have emphasized the need to consider seismic forces in the design and analysis of these towers.

2. OBJECTIVES

- To study Monopoles and Cable supported monopoles and study its benefits, uses and applications.
- To evaluate the Wind pressure on monopoles with 100% of exposure and on tower with 50% of exposure factor by using gust wind method.
- To analyse seismic & wind load behaviour of monopole, tower and monopole with rope support by FEA based software.
- Compare the analytical results with FEA based software Staad-Pro.
- To suggest best performing model with respect to lateral displacement.

3. MODELING AND LOADING DETAILS

a. Modeling of Self-Supporting Towers and Monopoles

The 3D modelling analysis was performed for three types of telecommunication towers: Self-Supporting Telecommunication Tower, Monopole, and Cable-Supported Monopole, with models designed at two different heights—30 meters and 21 meters. For the 30-meter monopole model, the tower features a tapered cylindrical shape with a base diameter of 2 meters and a top diameter of 0.6 meters. The plate thickness varies with height, using 20 mm at the base, 15 mm in the middle, and 10 mm at the top, and the structure is constructed from high-strength steel. The 30-meter self-supporting tower has a base width of 5 meters and tapers to 2 meters at the top, incorporating a D-bracing system for enhanced structural stability. Similarly, the 21-meter monopole model maintains the same base and top diameters, with plate thicknesses of 20 mm and 15 mm, also made from high-strength steel. The 21-meter self-supporting tower retains the same base and top dimensions as its 30-meter counterpart and uses the same D-bracing configuration. Additionally, a cable-supported monopole model was developed for both 30-meter and 21-meter heights. In this model, four cables are symmetrically connected to the monopole at a height of 18.76 meters, providing additional lateral support and improving the tower's stability under wind and seismic loads.

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Table 1. Details of members considered for 30m Monopole

Height	Diameter	Thickness of plate
0 to 3.01 m	2 - 1.8m	20 mm
3.01 to 6.023 m	1.8 – 1.6 m	
6.023 to 9.034 m	1.6 - 1.4 m	
9.034 to 12.046 m	1.4 – 1.2 m	
12.046 to 14.284 m	1.2 – 1 m	15 mm
14.284 to 16.523 m	1 – 0.8 m	
16.523 to 18.761 m	0.8 – 0.6 m	
18.761 to 21 m	0.6 – 0.6 m	
21 to 22.5 to 24 to 25.5 to 27 to 28.5 to 30 m	0.6 m	10 mm
Rope Details for Monopole		
Rope (4 No)	Diameter – 10 mm	Height – 18.761 Distance From Model- 5 m

Table 2. Details of members considered for 30m Self-Support Telecommunication

Tower member	Panel	Sections
Leg members	1-4	ISA 110 X 110 X 12
	5-8	ISA 90 X 90 X 12
	9-14	ISA 80 X 80 X 10
Horizontal members	1-8	ISA 65 X 65 X 10
	9-14	ISA 55 X 55 X 8
Bracing members	1-8	ISA 70 X 70 X 10
	9-14	ISA 55 X 55 X 8

Table 3. Details of members considered for 21mMonopole

Height	Diameter	Thickness of plate
0 to 3.01 m	2 - 1.8m	20 mm
3.01 to 6.023 m	1.8 – 1.6 m	
6.023 to 9.034 m	1.6 - 1.4 m	
9.034 to 12.046 m	1.4 – 1.2 m	
12.046 to 14.284 m	1.2 – 1 m	15 mm
14.284 to 16.523 m	1 – 0.8 m	
16.523 to 18.761 m	0.8 – 0.6 m	
18.761 to 21 m	0.6 – 0.6 m	
Rope Details for Monopole		
Rope (4 No)	Diameter – 10 mm	Height – 18.761 Distance From Model- 5 m

Table 4. Details of members considered for 21m Self-Support Telecommunication

Tower member	Panel	Sections
Leg members	1-4	ISA 110 X 110 X 12
	5-8	ISA 90 X 90 X 12
	9-14	ISA 80 X 80 X 10
Horizontal members	1-8	ISA 65 X 65 X 10
	9-14	ISA 55 X 55 X 8
Bracing members	1-8	ISA 70 X 70 X 10
	9-14	ISA 55 X 55 X 8

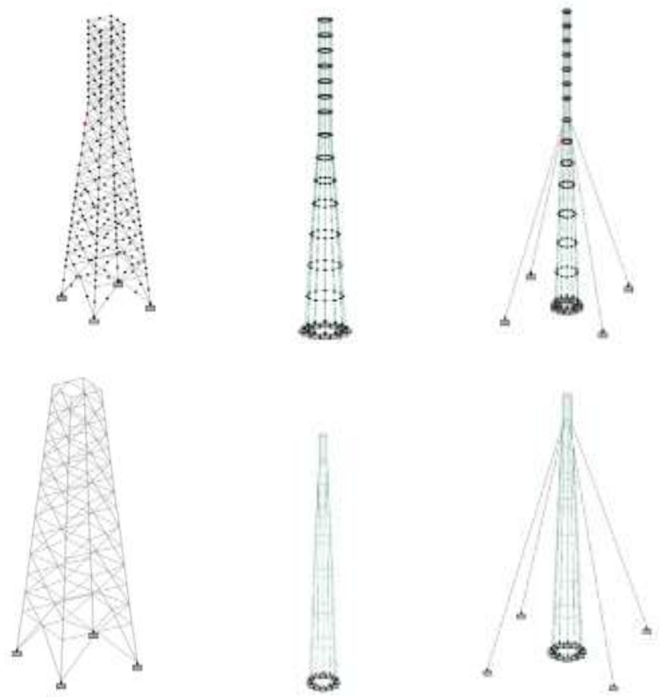

Figure 1: 6 Different Models with 30m and 21m heights.

b. Loads acting on towers

The only load considered in the analysis of the tower models is the self-weight of the structures. This includes the weight of all structural components such as the steel sections and plates used in the construction. No external loads like live loads were applied during this stage of the modeling.

c. Wind loads acting on towers

The wind load on the tower structure is calculated by using IS 875 (part 3): 2015. For the calculation of the wind load by the gust factor method the parameters considered are as follows, the basic wind speed is taken 39 m/sec, the probability factor k1 is taken as 1 (Mean probable design life of structure = 100 years), the Topography factor k3 is assumed to be 1 for plain terrain, the Terrain, height and structure size factor k2 is varying at different levels of the tower and is taken from IS code.

Table 5: Wind Load Intensity

Height	Vz	Pz	Cf	Gust	Ae	FZ	Force in Kn
7.9	39.00	23.40	0.02	8.56	142.2	569.8611	0.57
11.1	39.33	23.60	0.02	8.70	199.8	820.2217	0.82
14.3	39.65	23.79	0.02	8.81	257.4	1078.602	1.08

17.5	39.98	23.99	0.02	8.90	315	1344.513	1.34
20.7	40.30	24.18	0.02	8.98	372.6	1617.646	1.62
23.9	40.63	24.38	0.02	9.05	430.2	1897.774	1.90
27.1	40.95	24.57	0.02	9.11	487.8	2184.702	2.18
30.3	41.28	24.77	0.02	9.17	545.4	2478.237	2.48

d. Time History Analysis

Time history analysis is the study of the dynamic response of the structure at every addition of time, when its base is exposed to a particular ground motion. Static techniques are applicable when higher mode effects are not important. This is for the most part valid for short, regular structures. Thus, for tall structures, structures with torsional asymmetries, or no orthogonal frameworks, a dynamic method is needed.

El Centro earthquake data (Time Vs. Acceleration) were used to perform time history analysis. It was first earthquake to be recorded by a strong-motion acceleration which is widely used as a benchmark ground motion in structural engineering and seismic design. It has magnitude of 6.9. Its peak ground acceleration value is 0.348g (3.41m/s^2)

4. RESULTS AND DISSCUSSION

a. Wind Load Results for 30m and 21m Towers and Monopoles

The wind load analysis highlights the impact of tower height on structural displacement. Taller towers, such as the 30-meter models, exhibit greater lateral displacement compared to the shorter 21-meter towers due to increased exposure to wind pressure over a larger surface area.
Below graphs shows displacements in mm for 21m and 30 m.

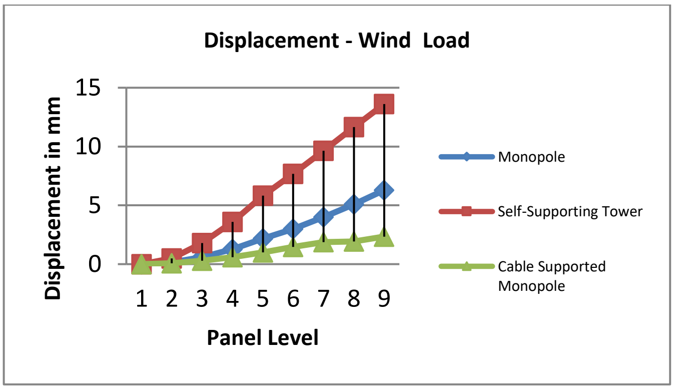

Figure 3. Displacements for 21m models in mm

Above Graph shows results of the Displacement for wind load on Self-Supported Tower, Monopole, and Cable Supported Monopole. As per the results monopole gives better results than the Self-Supported Tower by 40-50% and Cable Supported monopole gives better results than Monopole by 30-40%.

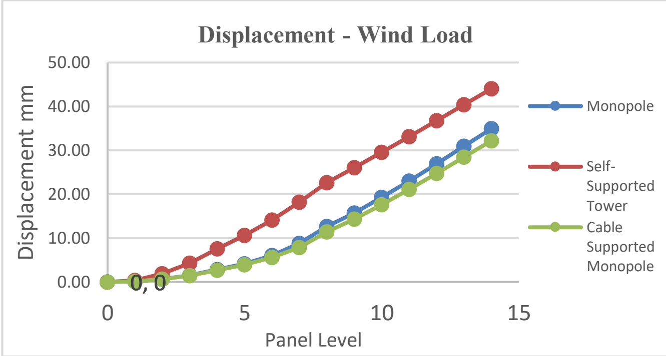

Figure 4. Displacements for 30m models in mm

Above Graph shows results of the Displacement for wind load on Self-Supported Tower, Monopole, and Cable Supported Monopole. As per the results monopole gives better results than the Self-Supported Tower by 20-30% and Cable Supported monopole gives better results than Monopole by 5-10%.

b. Time History Analysis Results

The results of the Time History analysis indicate that 30m towers show higher seismic displacement than 21m towers due to their increased height and flexibility. The detailed comparison is given below in the tables.

i.Time Period

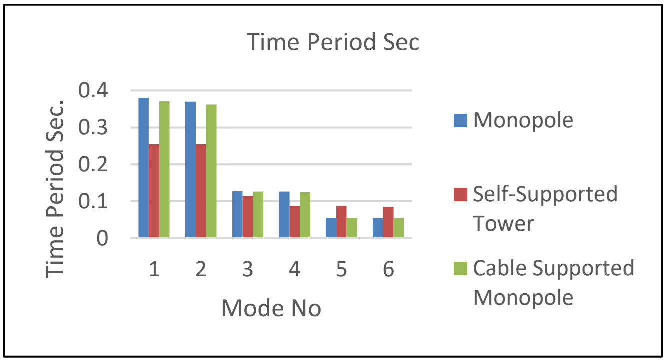

Figure 5. Time period for 30m models

Above Graph shows results of the Time Period for time history load on Self-Supported Tower, Monopole, and Cable Supported Monopole. As per the results Self-Supported Tower have less time period for mode 1- 4 and then it get increased for mode 5-6 than monopole and Cable Supported Monopole

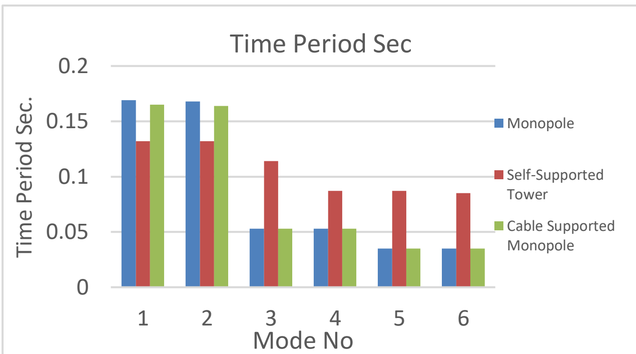

Figure 6. Time period for 21m models

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The graph shows that Monopole and Cable-Supported Monopole towers have similar dynamic behaviour, while the Self-Supported Tower has shorter time periods in lower modes, indicating higher stiffness and more complex vibration characteristics in higher modes.

ii. Frequency

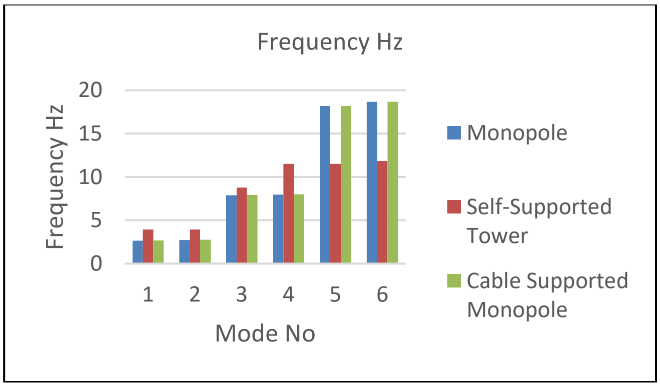

Figure 7. Frequency for 30m models

Above Graph shows results of the Frequency for time history load on Self-Supported Tower, Monopole, and Cable Supported Monopole. As per the results Self-Supported Tower has high Frequency for mode 1- 4 and then it get decreased for mode 5-6 than monopole and Cable Supported Monopole.

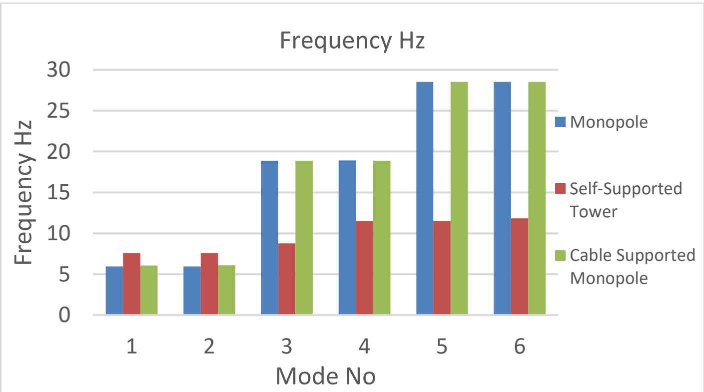

Figure 8. Frequency for 21m models

The graph shows Monopole and Cable-Supported Monopole have similar frequencies, indicating alike dynamic behaviour, while the Self-Supported Tower shows higher frequencies in lower modes and lower in higher modes, reflecting greater stiffness and different vibration characteristics.

iii.Time Vs. Displacements

Table 6. Comparisons results for 30m models for Time vs. Displacements.

Time Vs. Displacement			
Direction	Monopole	Self-Supported Tower	Cable Supported Monopole
X Axis	700	784	686
Y Axis	54.7	96.1	53.1
Z Axis	700	784	686

Table 7. Comparisons results for 21m models for Time vs. Displacements.

Time Vs. Displacement			
Direction	Monopole	Self-Supported Tower	Cable Supported Monopole
X Axis	854	374	804
Y Axis	86.7	26	26.3
Z Axis	887	364	832

iv. Time Vs. Acceleration

Table 8. Comparisons results for 30m models for Time vs. Acceleration.

Time Vs. Acceleration			
Direction	Monopole	Self-Supported Tower	Cable Supported Monopole
X Axis	22.7	24.2	23.4
Y Axis	0.979	2.88	1.74
Z Axis	23.9	24.2	24.4

Table 9. Comparisons results for 21m models for

Time vs. Acceleration.

Time Vs. Acceleration			
Direction	Monopole	Self-Supported Tower	Cable Supported Monopole
X Axis	42.8	32.9	43.2
Y Axis	1.86	2.28	1.82
Z Axis	44.8	32	44.9

5. CONCLUSION

- Among the three configurations, Self-Supporting Towers exhibited the highest displacement values under both wind and seismic loading.
- Monopoles reduced lateral displacement by approximately 24% for 30m height and 46% for 21m height compared to self-supporting towers, owing to their more streamlined form and uniform mass distribution.
- The Cable-Supported Monopole further improved performance, reducing displacements by 9% for 30m and 35% for 21m demonstrating enhanced control over structural deflection due to the added lateral restraint from cables.
- Self-supporting towers showed higher natural frequencies and lower time periods in the initial modes, indicating greater inherent stiffness.
- Cable-supported systems exhibited better vibration damping and dynamic stability, making them more effective in withstanding time-dependent loads such as seismic ground motion.
- Monopoles showed moderate performance but benefited significantly when reinforced with cable supports.
- Under time history analysis, Cable-Supported Monopoles showed the least acceleration response, which suggests better energy dissipation and seismic resilience.

- Wind analysis results based on the gust factor method confirmed that monopoles and cable-supported structures are more resistant to wind-induced vibrations and stress.
- From a construction and material usage perspective, monopoles may be more cost-effective for medium heights, while self-supporting towers are preferred for greater heights without space limitations.

6. REFERENCES

- Prachi A. Uchade et. al. “Experimental Investigation on Comparison of Lattice Tower and Monopole” International Journal for Research Trends and Innovation, Volume 7, Issue 4, (2022)
- Syed. Ehtesham Ali et. al. “Analysis and Design of Telecommunication Monopole Towers with and without Camouflaged” International Journal of Innovative Science, Engineering & Technology, Vol. 09 Issue 02, (2022)
- Shwetha Shetty M R et. al. “Dynamic Analysis of 4-Legged Steel Telecommunication Tower” International Journal of Civil Engineering and Technology (IJCIET) Volume 10, Issue 01, (2019)
- Ravichandran P et. al. “Behavior of Self-Supporting Communication Tower under Horizontal Loads” International Journal of Recent Technology and Engineering, Volume-8 Issue-4, (2019)
- Veena G et. al. “Seismic Analysis of Four Legged Telecommunication Towers using Fluid Viscous Dampers” International Research Journal of Engineering and Technology, Volume: 04, Issue: 06 (2017)
- M. Pavan Kumar et. al. “Effect of Wind Speed on Structural Behaviour of Monopole and Self-Support Telecommunication Towers” Asian Journal Of Civil Engineering (Bhrc) Vol. 18, No. 6 (2017)
- Keshav Kr. Sharma, et. al. “Comparative Analysis of Steel Telecommunication Tower Subjected To Seismic & Wind Loading”, Civil Engineering and Urban Planning: An International Journal (CiVEJ) Vol.2, No.3, (2015)
- Shubham P Patel, Title - “Performance of Telecommunications Tower during Seismic and Wind Loading Condition”, International Journal of Scientific Research & Engineering Trends, on July-Aug-2021.
- IS 875 part 3 “Design Loads (Other than Earthquake) for Building and Structures.