Performance Transition Analysis of Mono-Lattice Tower At 100ft, 150ft and 200ft Under Wind and Seismic Loading

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Abstract: Aesthetically pleasing and structurally sound tower systems that can withstand high winds and earthquakes are in high demand because to the fast growth of the telecommunications industry. The effect of wind and seismic loads on the performance transition of 100-foot, 150-foot, and 200-foot Mono-Lattice towers is compared. The Mono-Lattice tower is a combination of lattice towers and monopole towers, which combines the advantages of small footprint and beautiful appearance of monopole tower with that of higher rigidity and load-bearing capacity of lattice tower. Conforming to the requirements of IS 1893 (Part 1):2016, TIA-222-H, & IS 875 (Part 3):2015, Non-linear P-Delta analysis and Finite Element Analysis (FEA) have been carried out in the software tnxTower. One of several structural criteria that were tested was the height of the tower. These included base shear, bending moment and maximum horizontal deflection. The results showed that the wind exposure of the Mono-Lattice tower is lower than that of the full lattice tower and the wind induced deflection & bending moments are less than those of the traditional monopole tower. The Mono-Lattice's rigidity and serviceability improved at 100 ft height, having a deflection of only 0.536 in. in a wind. Additionally, compared to lattice and monopole towers, wind-induced bending moments was much lower, suggesting better structural efficiency and less need for foundations. The seismic base shear values were comparatively higher in the case of the Mono-Lattice tower making the foundation design considerations more critical. The general conclusions of the analysis will indicate that for medium to high rise telecom applications the Mono-Lattice layout will be the best combination of aesthetics, structural performance, wind rejections, and a low base cost.

Keywords: Mono-Lattice Tower, Telecom Tower, Wind Loading, Seismic Loading, P-Delta Analysis, Finite Element Analysis, Deflection, Base Shear, Bending Moment, Structural Efficiency

INTRODUCTION

With the fast expansion of Telecom network and the increasing demand of high-speed wireless communication technologies such as 4G & 5G, Telecom towers must be economically viable, aesthetically appealing and structurally efficient. Due to the excellent appearance and small footprint, monopole tower is used widely in the urban region; due to the excellent rigidity and load-carrying capacity, lattice tower is widely used. The two tower shapes are used in the telecom industry. Monopole towers at higher elevations experience the issue of bending moments and deflections that are greater than the lattice counterparts, and also require more space to install, and are exposed to more wind.

To overcome these deficiencies, a new hybrid structural solution (Mono-Lattice) has emerged, that incorporates some of the best attributes of monopole and lattice towers. The Mono-Lattice tower is a result of the combination of monopoles' slim profile and reduced land space requirements, and lattice systems' improved stiffness, structural stability. Such a hybrid solution is particularly suitable for medium to tall telecom towers because of its structural properties and flexibility in the urban context.

In this research, the strength of the structure of Mono-Lattice towers with heights of 100', 150' and 200' is studied under wind loading and seismic loading. The primary software used in this research is tnxTower, which is a Finite Element Analysis (FEA) and Non-linear P-Delta analysis tool to determine the critical structural parameters such as base shear, bending moment and maximum horizontal deflection. The study was performed under the TIA-222-H, IS 1893 (Part 1):2016 and IS 875 (Part 3):2015 considering the geology of Pune area and base wind speed of 39 m/s.

This is the motivation for this undertaking, which is basically to discover how the structural effectiveness & performance of Mono-Lattice towers vary with their height. The performance of monopole towers is satisfactory at low levels, but they can be very fragile at high (overturning) levels, and prone to excessive swaying. The lateral stiffness and the reduction of wind-induced reaction should be achieved by Mono-Lattice arrangement and mitigate these impacts. The research also aims to evaluate the effect of base shear & bending moments due to wind & seismic loads on the foundation requirements, with the help of measurement.

The results of the study will provide insight into the performance of the Mono-Lattice towers at different heights and demonstrate its suitability for modern telecommunication applications which seek optimal structural performance, minimised site footprint and enhanced serviceability.

OBJECTIVES

- To assess the Mono-Lattice towers' structural performance at 100, 150, and 200 feet when subjected to seismic and wind loads.
- To determine the most effective telecom tower layout by analyzing and contrasting deflection, base shear, & bending moment responses.

RESEARCH METHODOLOGY

In this study, the structural performance of 100-, 150-, and 200-foot Mono-Lattice telecom towers subjected to wind and seismic loading is evaluated. Critical structural parameters including deflection, bending moment, and base shear were studied using Finite Element Analysis (FEA) in tnxTower software, and the analysis was conducted in accordance with IS 875 (Part 3):2015, IS 1893 (Part 1):2016, & TIA-222-H standards. In order to examine crucial structural characteristics as base shear, bending moment, and deflection, tnxTower software was used for Finite Element Analysis (FEA) and non-linear P-Delta analysis. Standards such as TIA-222-H, IS 1893 (Part 1):2016, & IS 875 (Part 3):2015 were followed in conducting the analysis.

Non-linear P-Delta Analysis Method

The second-order effects caused by axial loads acting on distorted forms are captured by the extra moments created by the Non-linear P-Delta analysis. Because it takes into consideration the geometric non-linearity, which has a major impact on the performance and stability of tall, thin structures like telecom towers, this study approach is vital. The P-Delta effect is especially noticeable in monopoles, which are single continuous cantilevered structures. For precise Deflection and Base Bending Moment values in a comparative examination of 100ft, 150ft, & 200ft Monopole, Full Lattice, MonoLattice models & the P-Delta effect is crucial. The mono-lattice is an improvement over the monopole in terms of lateral displacement reduction because to its braced lattice construction. P-Delta analysis will determine the precise amount by which the secondary moment is reduced by the lattice's extra stiffness. The main argument in favor of the Mono-Lattice as a structurally better option than the Monopole at 150 and 200 feet in height is based on this comparison.

Numerical Method

Finite Element Analysis (FEA): The tnxTower program is a potent tool for making nonlinear behavior predictions and modeling complicated loading situations. Finite element analysis (FEA) models may account for geometric defects, non-linearities in the material, and specific loading circumstances. The program tnxTower was used for this. The non-linearities of the material, geometric flaws, and specific loading circumstances may all be included in FEA models.

Table 1: Topography Details

Type	Values
Region	Pune
Wind Speed	39 m/sec (88 mph)
Terrain Category	3
Importance Factor	1
Risk Coefficient	1
Topography Factor	1
Relevant Codes	IS 875 (Part 3): 2015, IS 1893 (Part 1): 2016, TIA-222-H

Table 2: Section properties for Monopole Tower

Sr. No.	Parameter	100 ft (30 m)	150 ft (45 m)	200 ft (60 m)
1	Base Diameter	3.57 ft	3.57 ft	3.57 ft
2	Top Diameter	1.38 ft	1.38 ft	1.38 ft
3	Number of Flats	18	18	18
4	Grade of Steel	A607-60	A607-60	A607-60

Table 3: Section properties for Mono-Lattice Tower

Sr. No.	Parameter	100 ft (30 m)	150 ft (45 m)	200 ft (60 m)
1	Lattice + Monopole Height	50 ft + 50 ft	80 ft + 70 ft	120 ft + 80 ft
2	Base Face Width	15 ft	18 ft	24 ft
3	Top Base Width	5 ft	6 ft	6 ft
4	Height of Section × Number	25 ft × 2	20 ft × 4	20 ft × 6
5	Number of Legs	4	4	4
6	Grade of Legs	A582-70	A582-70	A582-70
7	Leg Size Dia. × Thickness	ROHN 4” X-STR, ROHN 3” STD	ROHN 4” X-STR, ROHN 3” STD	ROHN 4” X-STR, ROHN 3” STD
8	Base Diameter	1.5 ft	2 ft	2 ft
9	Top Diameter	1 ft	1 ft	1 ft
10	Number of Flats	18	18	18
11	Monopole Grade	A572-65	A572-65	A572-65

Load Combinations

According to IS 875 Part 3:2015, IS 1893 Part-I:2016, or TIA-222-H, the towers were subjected to 37 different load combinations that covered both the Ultimate Limit State (ULS) and the Serviceability Limit State (SLS). The ULS combinations included factored dead or wind loads (1.2D + 1.0W and 0.9D + 1.0W) utilized at twelve different wind directions ranging from 0° to 330° in increments of 30°, for a total of 25 strength-level cases. In a total of twelve serviceability instances, SLS combinations include unfactored dead load (D + W) in all twelve directions. Included as well was a dead-load-only enclosure. The wind speed was 39 m/s, which is in line with the terrain of the Pune area (Terrain Category 3), and no ice loading was applied.

RESULT AND DISCUSSION

The structural behavior of 100-, 150-, and 200-foot Mono-Lattice towers subjected to wind and seismic loads was assessed using the findings derived from Finite Element Analysis (FEA) and Non-linear P-Delta analysis. In order to comprehend the towers' stability, stiffness, or structural efficiency, crucial structural measures like base shear, maximum horizontal deflection, and bending moment were used to evaluate their performance.

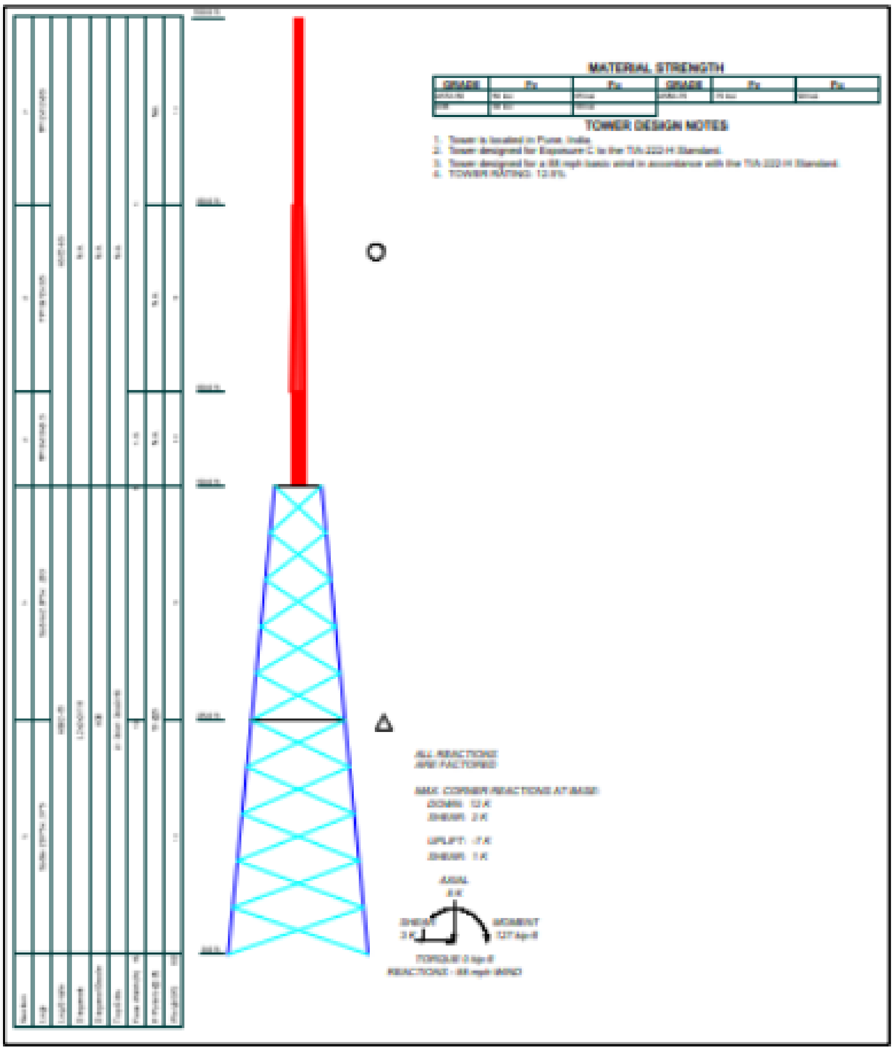

Figure 1: 100ft Mono-Lattice Tower

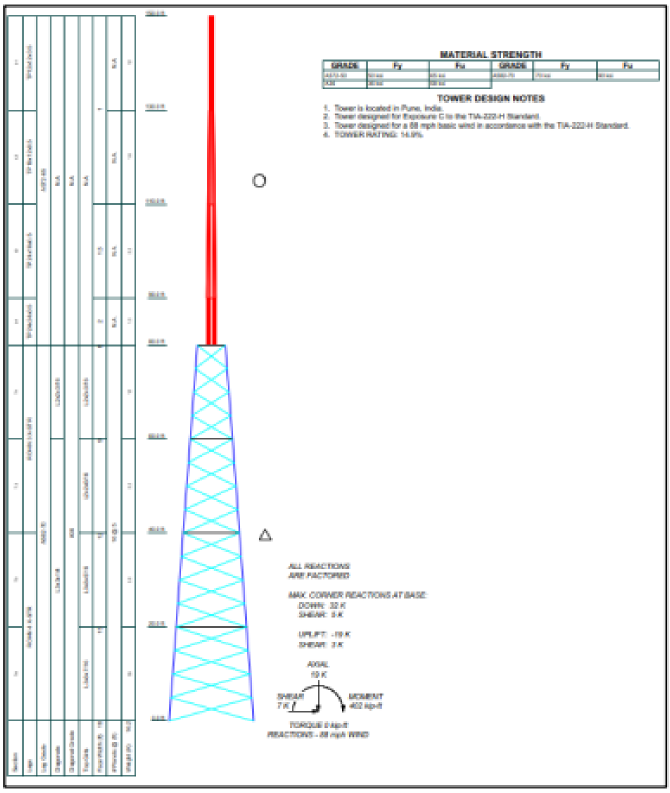

Figure 2: 150ft Mono-Lattice Tower

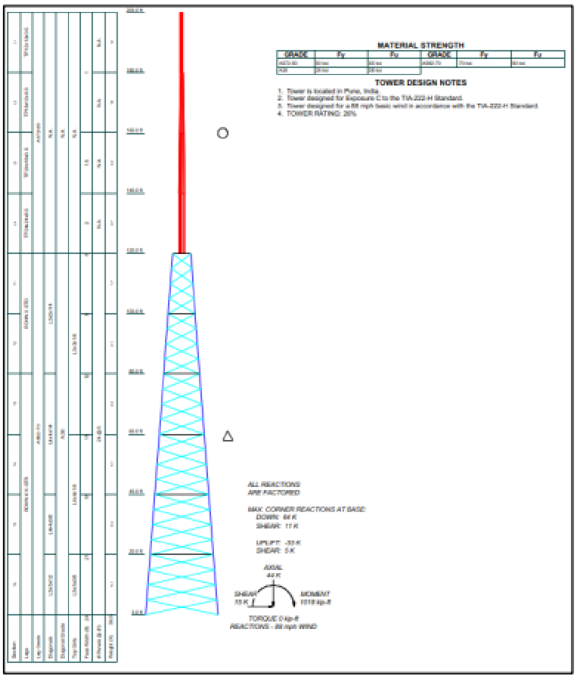

Figure 3: 200ft Mono-Lattice Tower

Table 4: Maximum Horizontal Deflection

Type of Tower	Height (ft)	Seismic Induced Displacement (in)	Wind Induced Displacement (in)
Mono-Lattice	100 ft	1.896	0.536
Mono-Lattice	150 ft	1.932	1.932
Mono-Lattice	200 ft	7.965	7.965

When compared to the Monopole (4.231 in) and the Mono-Lattice (0.536 in) at 100 ft, the former provides a considerable decrease in seismic-induced deflection (e.g., 1.896 in) and a large reduction in wind-induced deflection (4.231 in). This proves that the lattice integration successfully stiffened the tower, especially when it came to lower-level wind stresses.

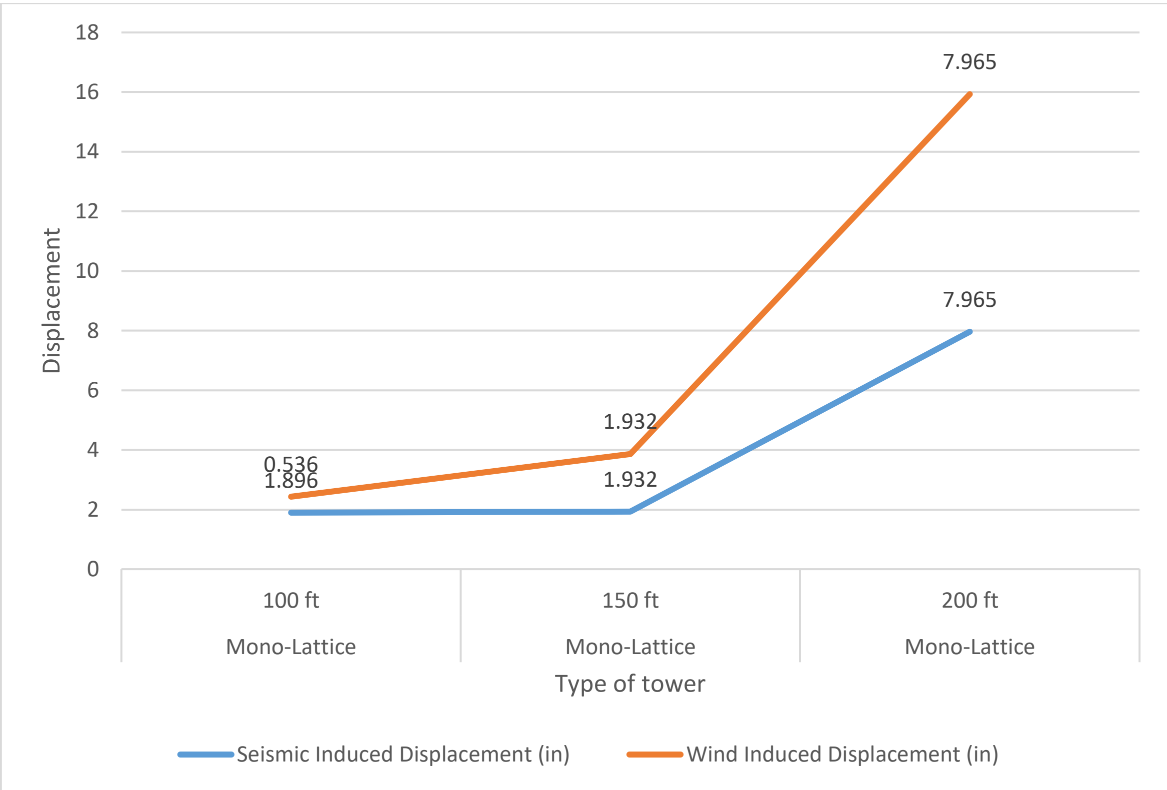

Figure 4: Maximum Horizontal Deflection

Table 5: Maximum Bending Moment Mono-Lattice

Height	Seismic BM (kN.mm)	Wind BM (kN.mm)
Mono-Lattice 100ft	50,174	1,72,218
Mono-Lattice 150ft	1,01,705	3,13,266
Mono-Lattice 200ft	2,48,155	5,45,335

Due to its strong wind base shear and considerable wind exposure, the Lattice tower receives the largest wind-induced BM, for example, 2,046,140 kNmm at 200 ft. With a wind BM of 545,335 kNmm compared to 1,127,084 kNmm at 200 ft for the monopole and 545,335 kNmm for the lattice tower, the mono-lattice design is clearly the most efficient structural form in wind resistance.

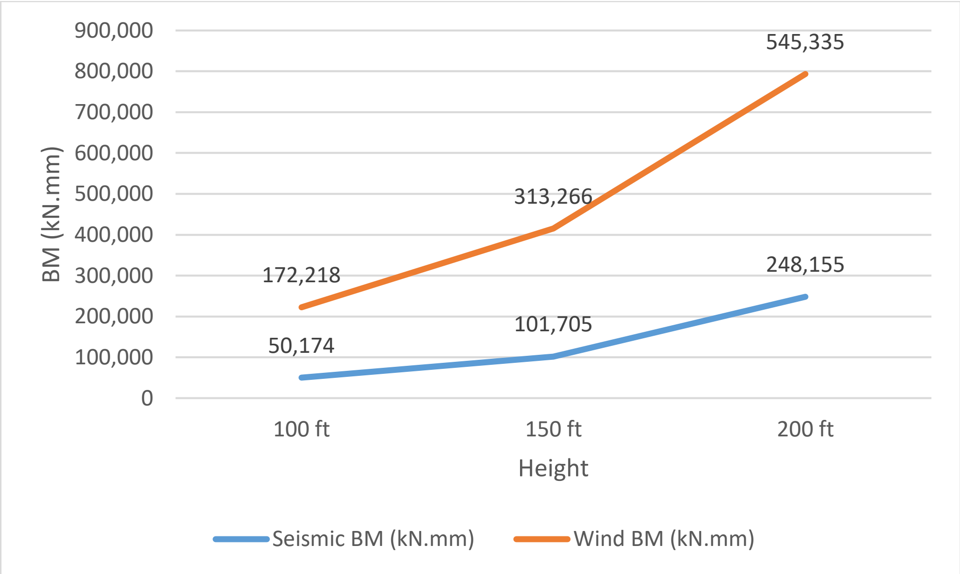

Figure 5: Maximum Bending Moment Mono-Lattice

Table 6: Base Shear

Type of Tower	Height (ft)	Seismic Induced Base Shear (kN)	Wind Induced Base Shear (kN)
Mono-Lattice	100 ft	8.4516	13.345
Mono-Lattice	150 ft	8.4516	31.137
Mono-Lattice	200 ft	10.586	66.723

The Mono-Lattice tower, on the other hand, reports a much larger seismic base shear (for example, 10.586 kN at 200 feet), which indicates that it has a bigger mass or a basic period that draws more seismic force. When designing the foundation, this is a vital factor to take into mind. Mono-Lattice towers exhibit much reduced wind base shear, which is to be anticipated given the relatively lower wind-exposed surface area as compared to other tower technologies.

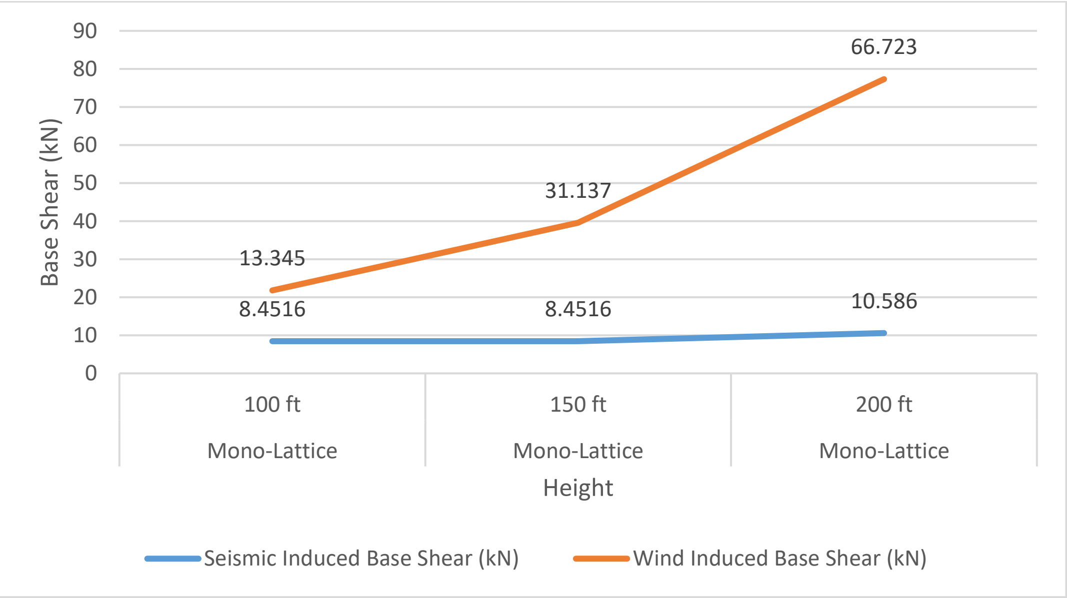

Figure 6: Base Shear

The Mono-Lattice tower is an effective solution that bridge the gap between the Lattice tower, which has a high degree of rigidity but a low level of aesthetic appeal, and the Monopole tower, which has a high degree of flexibility but a high level of aesthetic appeal.

Table 7: Mono-Lattice Performance

Performance Metric	Mono-Lattice Performance	Findings
Deflection	Significantly lower than Monopole (especially wind deflection at 100 ft), but higher than Lattice.	Improved Serviceability: Provides better stiffness than Monopole.
Wind BM	Significantly lower than both Lattice and Monopole.	Structural Efficiency: Requires smaller foundational elements and base plate due to reduced overturning moment.
Wind Base Shear	Similar to Monopole and much lower than Lattice.	Reduced Wind Load: Lower aerodynamic profile is confirmed.
Seismic Base Shear	Highest among all tower types.	Foundation Consideration: Requires a more robust foundation to resist higher seismic lateral forces.

While the Mono-Lattice design maintains the look of the Monopole and has a lower wind loading profile in comparison to the Lattice, it displays higher performance in reducing wind-induced bending moments and delivers better stiffness (lower deflection) in comparison to the Monopole design. The increased seismic base shear is the most significant constraint, and it is imperative that the foundation design take this into consideration.

CONCLUSION

This research used Non-linear P-Delta and Finite Element Analysis to examine the structural behavior of 100-, 150-, and 200-foot Mono-Lattice telecom towers subjected to wind and seismic loads. A combination of the structural benefits of lattice towers alongside the compact & visually beautiful features of monopole towers is achieved by the Mono-Lattice structure, as shown by the results. Lower wind-induced deflection & bending moments were observed in the Mono-Lattice tower in comparison to the traditional monopole tower, suggesting that the former is more rigid and efficient structurally. With less wind-induced bending moment, there is less chance of overturning and less foundation needs, which means the approach is good for communications infrastructure financially. The Mono-Lattice design was also shown to be aerodynamically efficient due to the reduced wind base shear. The research did find the fact that Mono-Lattice tower has a larger seismic base shear than other tower types, particularly at higher heights, thus it's important to be cautious when designing the foundation and anchorages. Although this is a drawback, the Mono-Lattice tower outperformed other medium & tall telecom structures in terms of space efficiency, strength, stiffness, and wind resistance. In urban areas, when land availability, aesthetics, & structural performance are paramount, the Mono-Lattice tower offers an optimal solution for contemporary telecom applications.

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