

Dynamical Structural Performance of Steel Mast to Telecom Facilities Using Staadpro

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ABSTRACT: The expansion of wireless communication infrastructure has intensified the demand for safe, lightweight, and dynamically stable steel masts. This study investigates the dynamic structural performance of a 55 m self-supporting lattice telecommunication mast analysed and designed using STAAD.Pro. Loads considered include dead, live, wind, seismic, and accidental actions, evaluated according to Eurocode 3, TIA-222-G and the Uniform Building Code (UBC 1997). The methodology comprised geometric modelling, material definition, code-based load generation, and dynamic response evaluation under serviceability and ultimate limit states. Results show that maximum lateral deflection and member utilisation ratios remained within permissible code limits. The computed maximum horizontal deflection of 0.123m at the mast tip (ULS) is less than the allowable (0.550m) which is 1% of the tower height 55m, while the maximum vertical displacement is 1.262mm which is less than the allowable ($L/250 = 13.292\text{mm}$). These outcomes validate the reliability of STAAD.Pro for slender steel mast design and confirm the structure's compliance with international standards.

Keywords: Steel Mast; STAAD Pro; Eurocode; ANSI/TIA-222-G; UBC; Wind Load; Serviceability

1.0 INTRODUCTION

Steel masts are indispensable for telecommunication networks, broadcasting, and renewable-energy systems. Their tall and slender geometries make them highly sensitive to dynamic actions from wind and earthquakes. Failures arising from under-designed connections, fatigue, or buckling have been reported globally, underlining the need for rigorous code-compliant analysis.

Earlier design approaches relied heavily on manual calculations and empirical factors, often neglecting second-order effects and dynamic interaction between members. The adoption of computer-aided design software such as STAAD.Pro enables realistic simulation of load behaviour, geometric non-linearity, and vibration modes, improving both accuracy and economy.

This research focuses on the dynamic structural performance of a 55 m self-supporting lattice mast intended for telecom installations. The objectives are to:

1. Model the mast in STAAD.Pro using realistic geometry and material properties.
2. Apply and combine load cases per Eurocode 3, TIA-222-G, and UBC 1997.
3. Assess member forces, deflections, and stability under service and ultimate limit states.
4. Verify compliance with design-code criteria and evaluate seismic performance.

2.0 LITERATURE REVIEW

The reviewed literature highlights the evolution of structural design methods for steel masts, emphasizing the transformative role of STAAD Pro in enabling precise, efficient, and code-compliant analysis. Studies show that STAAD Pro effectively handles complex loading conditions such as wind, seismic, and dynamic effects—while

optimizing member design and supporting multiple international standards including Eurocode, ANSI/TIA and UBC code. Researchers such as Vaikuntham & Sudha (2020), Marjanović & Petronijević (2019), and Mastura et al. (2017) confirm the software's reliability for tall slender structures. The review further explores mast typologies (self-supporting, guyed, monopole, lattice, and hybrid), their structural behaviors, and common failure modes such as buckling, fatigue, and foundation instability.

3.0 METHODOLOGY

3.1 Structural Modelling

The mast is a 55 m high free-standing lattice tower composed of circular hollow-section legs (CHS 273×14.2 mm) and angle-section bracings (L100×100×10 mm, L75×50×10 mm, L50×50×5 mm). Geometry comprises two zones:

Zone A (0–45 m) — tapered from 7.5 m base width to 1.5 m at the transition.

Zone B (45–55 m) — constant 1.5 m width supporting antenna assemblies.

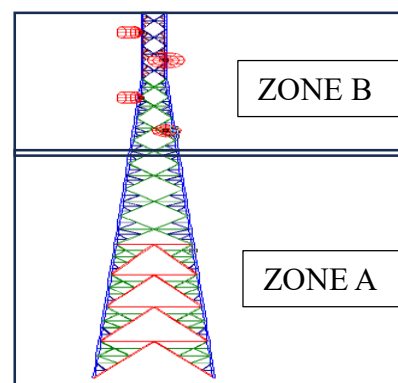


Fig 1: Steel Mast showing Zone Classes

Penalization employed 15 segments with K5L5 bracing at the lower panels and XM12 bracing at the upper portion for enhanced lateral stiffness (see Fig. 3). All base nodes were assigned fixed supports to simulate foundation restraint.

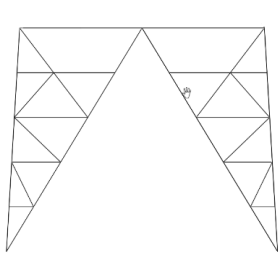


Figure 2: K5L5 bracing

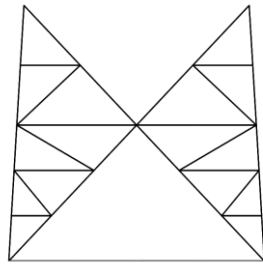


Figure 3: XM12 bracing

3.2 Material Properties

Table 1: Material Properties used

Steel grade	S275
Yield strength	275 N/mm ²
Young modulus of steel	210000 N/mm ²
Poison ratio	0.3
Steel Density	7850 Kg/m ³
Shear Modulus, G	105 N/mm ²

3.3 Design Codes

EN 1993-3-1 (2006) — Design of steel towers, masts, and chimneys.

EN 1991-1-4 (2005) — Wind actions.

TIA-222-G (2005) — Telecommunication structures.

UBC (1997) — Seismic design provisions. Load combinations followed EN 1990 for both SLS and ULS conditions.

3.4 Loading

3.4.1 Wind Load

The basic wind speed for the project location is taken as 35.6 m/s, based on the Nigeria Isoleths from the Nigerian Code of Practice Part 1 (NCP1), 1973, which represents a 3-second gust wind speed corresponding to a 50-year return period

Table 2: Wind pressure calculated per elevation

Wind pressure at elevation								
Ele v. (z)	z/z ₀	k _r	ln(z/z ₀)	c _r (z)	v _m = c _r (z)*v _b	σ _v = k _r *v _b *k _t	I _v	q _p [N/m ²]
5	10/0	0.19	4.61	0.87	21.72	4.72	0.22	743.21
10	20/0	0.19	5.30	1.01	24.99	4.72	0.19	906.14
15	30/0	0.19	5.70	1.08	26.90	4.72	0.18	1007.65
20	40/0	0.19	5.99	1.14	28.26	4.72	0.17	1082.44
25	50/0	0.19	6.21	1.18	29.31	4.72	0.16	1142.04

30	60/0	0.19	6.40	1.22	30.17	4.72	0.16	1191.76
35	70/0	0.19	6.55	1.24	30.90	4.72	0.15	1234.52
40	80/0	0.19	6.68	1.27	31.53	4.72	0.15	1272.10
45	90/0	0.19	6.80	1.29	32.09	4.72	0.15	1305.65
50	100/0	0.19	6.91	1.31	32.58	4.72	0.14	1336.00
55	110/0	0.19	7.00	1.33	33.03	4.72	0.14	1363.71

3.4.2 Seismic Load

Seismic Zone factor = 0.075 - Ref: Table 16-I, 1997 Uniform Building Code

Building Seismic coefficient 'Cv' = 0.26 - Ref: Table 16-R, 1997 Uniform Building Code

Building Seismic coefficient 'Ca' = 0.19 - Ref: Table 16-Q, 1997 Uniform Building Code

Soil profile type for seismic activity consideration = 1 - Ref: Table 16-J, 1997 Uniform Building Code

The Base shear was derived according to staad, then staad distribute the shear load vertically and horizontally.

$$\text{Base Shear (V)} = \frac{ZISW}{R_w}$$

Where Z - Seismic Zone Factor, I – Importance Factor, S – Site Coefficient (depending on the soil), W- Seismic Weight (Total mass considered), R_w – Response Modification Factor

3.4.3 Accidental Load

Table 3: Accidental Load

Reference	Computation			Output	
	Accidental load			Value	Unit
EN 1991-1-7:2006 Clause 4.3	Accidental Action	q	=	3	kN

3.4.4 Rest Platform Load

Table 4: Rest Platform Load

Reference	Computation			Output	
	Maintenance Load			Value	Unit
EN 1993-3-1:2006 Clause	Maintenance Load on rest platform	q	=	2	kN/m ²

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	Rest platform	R_p	=	3	No s
	Area of first rest platform	A_{p1}	=	3.68 43	m ²
	Area of second rest platform	A_{p2}	=	1.47 79	m ²
	Area of third rest platform	A_{p3}	=	0.34 49	m ²
	Load on first rest platform	W_1	=	7.36 86	kN
	Load on second rest platform	W_2	=	2.95 58	kN
	Load on third rest platform	W_3	=	0.68 98	kN
	Points Loads on Rest platform 1 nodes	$P_1 = W_1/4$	=	1.84 215	kN
	Points Loads on Rest platform 2 nodes	$P_2 = W_2/4$	=	0.73 895	kN
	Points Loads on Rest platform 3 nodes	$P_3 = W_3/3$	=	0.17 245	kN

3.4.5. Load Combination

Table 5: Summary of Load Combinations

Combination ID	Expression
101	1.0DL
102	1.0DL + 1.0LL
103	1.0DL + 1.0LL + 0.6W(X)
107	1.0DL + 0.7LL + 1.0W(X)
201	1.35DL
202	1.5 EQL (-X) + 0.9DL
301	1.35DL
306	1.35DL + 1.5LL + 1.5AL + 0.9W(-Z)

4.0 RESULTS AND DISCUSSION

4.1 Analysis Procedure

A 3-D finite-element model was constructed using beam elements. STAAD.Pro automatically computed self-weight

Table 7: Member capacity summary

Staad Ref	Beam No	Section	Max U.C	Allowable Ratio	Load Case Number	Remark
R1	1927	L100X100X10	0.866	1.000	306	Pass
R2	1318	L75X75X10	0.727	1.000	306	Pass
R3	435	L50X50X5	0.915	1.000	306	Pass
R4	440	L30X30X5	0.801	1.000	306	Pass
R5	1888	CHS273x14.2	0.875	1.000	306	Pass

4.4 Support Reactions

Maximum support reactions under ULS combinations occurred at Load Case 108 (Wind +X), giving a vertical reaction of 587.079 kN per leg. The foundation was therefore designed for combined axial and bending actions within concrete bearing limits

4.5 Connection Design

Base plates and anchor bolts were verified using RAM Connection. Maximum anchor tension = 146.7.5 kN < design capacity = 150 kN. Concrete bearing stress = 2.31 N/mm² <

and generated load combinations according to the selected codes. Second-order (P-Δ) and modal analyses were performed to capture geometric non-linearity and natural frequencies. Deflection limits and member stresses were checked against Eurocode criteria.

4.2 Deflection and Stability

The maximum lateral deflection recorded at the mast tip under the critical ULS load combination was 0.123 m. The allowable limit per TIA-222-G is 1% of 55m = 0.550m; therefore, the structure satisfies serviceability requirements. Vertical deflection was limited to L/250 = 13.292mm which was above 1.262mm that happened recommended by EN 1993-3-1.

Table 6: Maximum Horizontal Deflection

	Value (m)	Node	Load Case
Maximum Horizontal deflection	0.123	53	108
Tower Height = 55m, Max vertical deflection = 0.123 1% of 55m = 0.550 m > 0.123 Clause 4.5.6 of ANSI/TIA-222-G-2005 Therefore, deflection is Okay			

Table 7: Maximum Vertical Deflection

	Value (mm)	Node	Load Case
Maximum Vertical deflection	1.262	490	308
The maximum vertical deflection occurred at node 490. The member length is 3.323 m As per Euro code 1 1991 requirements. 3323/250 = 13.292 mm (Allowable). Therefore, the max is less than the allowable. Therefore, deflection is Okay			

4.3 Member Utilisation

All structural members exhibited utilisation ratios below 1.0. The most critical leg member attained 0.915 under ULS . These values indicate sufficient reserve capacity and proper section selection.

2.5 N/mm² limit. Thus, both steel and concrete interfaces remain safe under ultimate loads.

The maximum support reaction for the Ultimate Limit State (587KN) combination was used to design check for the base plate.

5.0 CONCLUSION AND RECOMMENDATION

This investigation demonstrated that STAAD.Pro provides a reliable analytical environment for assessing the dynamic behaviour of tall slender steel masts. The 55 m self-

supporting lattice tower satisfied all strength and serviceability criteria under wind, seismic, live, and accidental loads. Key conclusions are:

1. Maximum lateral and vertical deflections were well below permissible limits.
2. Member utilisation ratios < 1.0 confirmed adequate section capacities.
3. Modal and seismic analyses indicated stable response and no resonance issues.
4. Integration of Eurocode 3, TIA-222-G, and UBC 1997 within STAAD.Pro ensures global applicability and safety compliance.

The Recommendations are:

Based on the study's findings, several key recommendations are proposed to improve both academic research and engineering practice in mast design.

Firstly, engineers should prioritize the use of advanced computational tools such as STAAD Pro, SAP2000, and ANSYS, which provide higher analytical accuracy particularly for assessing dynamic and nonlinear behavior than traditional manual methods.

Secondly, even in regions classified as low-to-moderate seismic zones, such as Nigeria, seismic design considerations should be incorporated to enhance structural resilience and ensure alignment with global standards.

Post-construction maintenance should involve periodic inspection of joints, welds, and foundations for signs of corrosion or fatigue, with the adoption of structural health monitoring systems for proactive failure detection. Additionally, comprehensive geotechnical investigations are recommended to mitigate foundation-related issues, especially in self-supporting masts where base fixity is critical to overall stability.

Future design research should investigate the use of high-strength and corrosion-resistant materials, as well as aerodynamic control measures such as damping devices and streamlined geometries to reduce wind-induced vibrations, particularly in masts exceeding 70 m in height. Finally, it is recommended that regulatory authorities and government agencies establish unified national guidelines based on Eurocode and TIA standards to ensure design consistency and minimize structural failures.

Implementing these measures will significantly enhance the safety, sustainability, and service life of steel masts while supporting the reliability of telecommunication infrastructure.

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