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Analysis and Structural Optimization of Telecommunication Tower Using STAAD Pro Software

Prajwal Shinde¹, Prof. Deepak Patil²

P.G. Student, Department of Civil Engineering (Structural), S.G. Balekundri Institute of Technology, Belagavi, India¹

Associate Professor, Department of Civil Engineering, S.G. Balekundri Institute of Technology, Belagavi, India²

ABSTRACT: Self-supporting towers are frequently used for broadcasting, information transport, and telecommunications across the globe. Elevated antennas were necessary for emergency response system towers to properly send and receive radio signals. The more lateral pressures the tower is subjected to and the more likely it is to sway, the taller it is. Damages will result from this tower failing, and crucial communications will be halted. Using an X-bracing system and section layouts, four-legged telecommunication towers with heights of 30 meters, 45 meters, and 60 meters are developed, optimized, and compared in this context (both pipe and angular sections). Additionally, it is required that the supports at the tower's foundation be pinned. The tower is subjected to wind load, dead load, live load, and self-weight. A design aid for wind force and connection has been created using MS Excel after manual wind force calculations using the force coefficient approach. Considering wind speeds at various heights in compliance with IS 875 (Part 3): 2005, STAAD. Pro is employed for modelling and analysis of the structure.

KEYWORDS: Self-supporting towers, X-bracing, Staad pro.

I. INTRODUCTION

With more than seven million new mobile users being added each month, the Indian telecom services industry is the one that is expanding the quickest in the entire world. Mobile carriers face hurdles in terms of enhancing and modernizing infrastructure to maintain the caliber of services as a result of this rising base. An operator may need more tower sites to handle more users due to a rapidly growing subscriber base and a stricter spectrum allocation scheme.

Self-supporting towers are frequently used for broadcasting, information transport, and telecommunications across the globe. Elevated antennas were necessary for emergency response system towers in order to properly send and receive radio signals. The more lateral pressures the tower is subjected to and the more likely it is to sway, the taller it is. This tower's failure will result in damage and impede crucial communication.

Telecom towers use cantilever action to counteract wind load and function as vertical trusses. Cross bracing is one of the most popular layouts. The bracing members are set up in a variety of ways that either carry only tension or, alternatively, both tension and compression. When it is intended to resist just tension, the bracing consists of crossed diagonals. In accordance with the wind's direction, one diagonal absorbs all the stress while the other diagonal is supposed to be dormant. Smaller in cross-section, tensile bracing is typically constructed of back-to-back channel or angle sections. Different types of bracing systems are used frequently, including single diagonal, double diagonal (X-X), X-B, XBX, arch, subdivided V, diamond lattice, K, Y, W, and X bracings.

The height of a tower, which is typically far larger than its other measurements, is its most important feature. Because the space used on the ground level is so small, thin structures are frequently employed. Due to the decreased design forces, the tapering portion of the tower is advantageous in terms of bracing. The tower's ability to broadcast radio signals over a longer distance will increase with height. Due to its greater propensity to wobble, higher structures are more vulnerable to lateral loads like wind load. The compression component would buckle if the bracing were insufficient, which would result in the tower failing. For creating stiffness and resistance to wind stresses, diagonal braces are effective building blocks.

High-intensity winds (HIW) continue to be the main factor in telecommunication tower failures all over the world, and the fundamental challenge is that because these estimates are probabilistic, they are difficult to make. In tower modelling, the wind is more important than seismic forces, although the seismic impact cannot be ignored.

II. RELATED WORK

P. Markandeya Rajuet. al [1]. In this research, the towers are examined for six distinct fundamental wind speeds that are taken into account in accordance with IS 875: 2015. (PART 3). The authors, Keshav Kr. Sharma et al. [2], in this study, several bracing patterns are used to conduct a comparative analysis for different tower heights in India's Wind Zones I to VI and Earthquake Zones II to V. In [3], comparison study using the response spectrum approach is being conducted in India with the aid of the required software for varied ground level conditions due to the lack of complete Indian design codes provisions for dynamic analysis of telecommunication towers. Jithesh Rajasekharan et. al [4]. In this dissertation, research on models of various heights with various seismic and wind effect bracing has been done. The gust factor approach is used to study the impact of the wind on the structure, and the modal analysis and response spectrum analysis are used to study the impact of the earthquake on the structure. The results of the analysis mentioned above are tallied, contrasted, and conclusions are reached. In [5], The goal of this study was to determine the most cost-effective bracing mechanism for a specified range of tower heights. Different bracing techniques for towers of 40 and 50 metres in height have been studied while being subjected to wind stresses. Towers have been found to be more vulnerable to the diagonal wind. The ideal bracing arrangement has been found and reported.

IV. METHODOLOGY

In this context, four-legged tele-communication towers with heights of 30m, 45m and 60m are designed, optimized and compared utilising x - bracing system and section layouts (both pipe and angular sections). It is also stipulated that the supports at the foundation of the structure are pinned. The structure is subjected to self-weight, dead load, live load and wind load. Manual calculations of wind force using method of force coefficient have been done and design aid for wind force and connection has been prepared using MS. Excel. Taking into account wind speeds at various heights in accordance with the requirements of IS 875 Part 3. STAAD.Pro is used for the structure's modelling and analysis.

Design parameter for towers

Sl no	Height of tower	30 m	45m	60m
1.	Top width of tower	1.5 m	2.5 m	3.5 m
2.	Base width of tower	4 m	6 m	7.5 m
3.	Top straight portion	8 m	11 m	12 m
4.	Slant portion	22 m	34 m	48 m
5.	Type of bracing	X bracing	X bracing	X bracing
6.	Location	Vijayawada	Nasik	Bengaluru
7.	Terrain category	2	2	2

Antenna loading for all the towers

SL. No	Item	Quantity	Diameter (m)	Weight of the antenna (kg)
1.	Microwave 1	1	1.2	77
2.	Microwave 2	1	0.6	45
3.	CDMA	6	0.26 x 2.5 x 0.15m	20

Loads on tower

- Weight of the platform = 0.80 kN/m²
- Weight of the railing = 0.30 kN/m
- Weight of ladder and cage = 0.65 kN/m
- Live load on tower = 1 kN

Wind load on Tower and antennae

1. 30 m

- Microwave 1 = 1.131 x 1.4 x 1.845 = 2.92 kN

- Microwave 2 = $0.283 \times 1.4 \times 1.845 = 0.73 \text{ kN}$
- CDMA = $0.65 \times 1.8 \times 1.845 = 2.16 \text{ kN}$

Wind load on tower

SL.NO	SEGMENT	HEIGHT (m)	WIND LOAD
1	Segment 1	15 m	1.75 kN/m
2	Segment 2	22 m	1.44 kN/m
3	Segment 3	30 m	1.34 kN/m

2. 45 m

- Microwave 1 = $1.131 \times 1.4 \times 1.075 = 1.70 \text{ kN}$
- Microwave 2 = $0.283 \times 1.4 \times 1.075 = 0.43 \text{ kN}$
- CDMA = $0.65 \times 1.8 \times 1.075 = 1.26 \text{ kN}$

Wind load on tower

SL.NO	SEGMENT	HEIGHT (m)	WIND LOAD
1	Segment 1	14 m	1.56 kN/m
2	Segment 2	34 m	1.53 kN/m
3	Segment 3	45 m	1.23 kN/m

3. 60 m

- Microwave 1 = $1.131 \times 1.4 \times 0.770 = 1.22 \text{ kN}$
- Microwave 2 = $0.283 \times 1.4 \times 0.770 = 0.31 \text{ kN}$
- CDMA = $0.65 \times 1.8 \times 0.770 = 0.9 \text{ kN}$

Wind load on tower

SL.NO	SEGMENT	HEIGHT (m)	WIND LOAD
1	Segment 1	18 m	1.330 kN/m
2	Segment 2	33 m	1.164 kN/m
3	Segment 3	48 m	1.055 kN/m
4	Segment 4	60 m	1.086 kN/m

Modelling**Design parameters for all the tower section.**

1. CODE IS 800 – LSD
2. FU – 410000 kN/m^2 (ultimate tensile strength of steel)
3. FYLD – 250000 kN/m^2 (yield strength of steel)
4. ALPHA – 0.6 (end connection ,1 or 2 bolts)
5. MAIN – main column = 180 (allowable slenderness limit for compression member)
6. MAIN – bracing = 250 (allowable slenderness limit for compression member)
7. TMAIN – 400 (allowable slenderness limit for tension member)

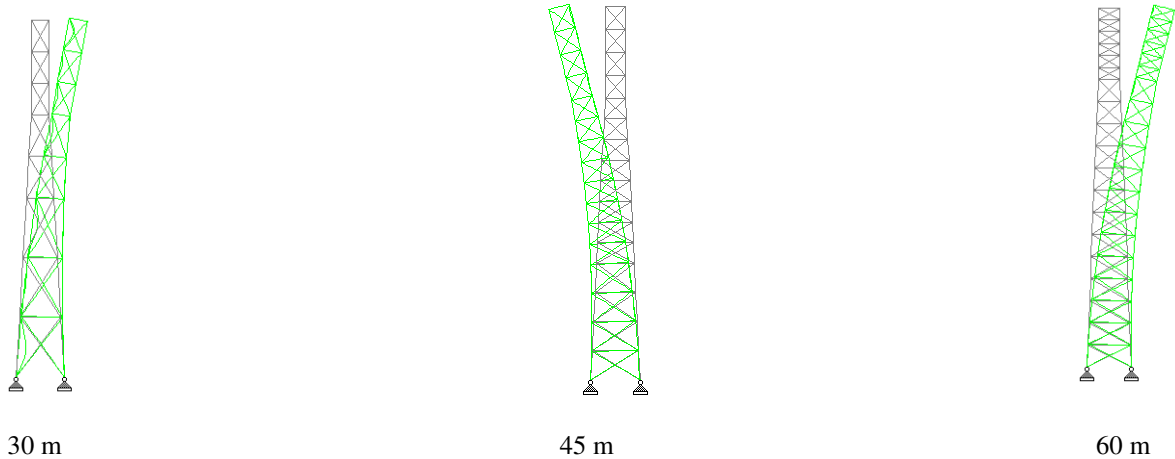
Deflection of tower

Fig.1. figures showing deflection of towers

V. EXPERIMENTAL RESULTS**Comparison of sections**

SL.NO	30m	Angle section	Angle + pipe section	Pipe section
1.	Deflection	49.765mm	94.300mm	124.778mm
2.	Footing Reaction	X = 3.275 kN Y = 22.168 kN Z = 3.275 kN	X = 4.810 kN Y = 19.384 kN Z = 4.810 kN	X = 1.618 kN Y = 9.752 kN Z = 1.618 kN
3.	Weight of the structure	88.656 kN 8.9 ton	77.538 kN 7.78 ton	39.008 kN 3.92 ton

SL.NO	45m	Angle section	Angle + pipe section	Pipe section
1.	Deflection	115.43mm	212.55mm	264.859 kN
2.	Footing Reaction	X = 4.483 kN Y = 39.532 kN Z = 4.438 kN	X = 6.582 kN Y = 35.283 kN Z = 6.582 kN	X = 2.173 kN Y = 18.413 kN Z = 2.173 kN
3.	Weight of the structure	158.127 kN 15.9 ton	141.131 kN 14.2 ton	73.653 kN 7.4 ton

SL.NO	60m	Angle section	Angle + pipe section	Pipe section
1.	Deflection	137.95mm	256.25mm	292.053
2.	Footing Reaction	X = 8.406 kN Y = 79.871 kN Z = 8.406 kN	X = 12.253 kN Y = 73.712 kN Z = 12.253 kN	X = 2.815 kN Y = 32.815 kN Z = 2.815 kN
3.	Weight of the structure	319.484 kN 32.1 ton	294.847 kN 29.6 ton	131.259 kN 13.2 ton

VI. CONCLUSION

- All loads including dead load, live load and wind load have been successfully engineered to withstand telecommunication tower.
- As a result of comparing [angle and angle + pipe section] and [angle + pipe and pipe section], it has been shown that for a height of 30 meters, there is an increase in deflection with 53% when angle + pipe section is used and with 76% when only pipe section is used respectively. Similarly, for 45m, 54% and 80%, for 60m, 54% and 88%.
- As a result of comparing [angle and angle + pipe section] and [angle + pipe and pipe section], it has been shown that for a height of 30 meters, there is reduction in footing reaction with 13% when angle + pipe section is used and with 50% when only pipe section is used respectively. Similarly, for 45m, 11% and 48%, for 60m, 8% and 56%.
- As a result of comparing [angle and angle + pipe section] and [angle + pipe and pipe section], it has been shown that for a height of 30 meters, there is a decrease in weight with 13% when angle + pipe section is used and with 50% when only pipe section is used respectively. Similarly, for 45m, 11% and 48%, for 60m, 8% and 55%.
- According to the results of this study, a pipe section with a X-bracing pattern is shown to be the most efficient and cost-effective for 30m, 45m and 60m tall, four-legged tele communication tower.
- It is concluded that there is decrease in footing reaction and weight, when the tower is constructed using angular section and angular + pipe section and increase in deflection when the tower is constructed using only pipe section.

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