

A COMPUTATIONAL EVALUATION OF VARIOUS BRACING TECHNIQUES FOR WIND-LOADING TELECOMMUNICATION TOWERS USING STAAD PRO V8I

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ABSTRACT

In today's telecommunications business, communication towers are extremely important for the transmission of data and information. Self-supporting lattice towers are the most popular type of telecommunications construction in use today. These towers are exposed to some of the most extreme weather conditions, including strong winds, earthquakes, etc. As one lattice tower design may be utilized for the building of several towers, greater emphasis might be placed on the study and design of these structures while also taking into account economic factors. By comparing deflection under operational wind load and the necessary quantity of steel, this research sought to identify the tower's optimal bracing arrangement in terms of strength and cost. The tower considered was a four-legged steel lattice tower with different types of bracing such as K, V, X and Y were to be compared. The elevation of the tower was taken as 24 m. Towers were analyzed and designed using Staad Pro V8i software as per IS 800-2007. The section used in designing was the angle section. The loads which were considered were dead load, live load, and wind load which was calculated as per IS 875-2015 Part 1 (Dead Load), IS 875-2015 Part 2 (Imposed Load) and IS 875-2015 Part 3 (Wind Load).

Keywords: lattice tower, bracing, Staad Pro V8i, self-supporting tower, telecommunication

1. INTRODUCTION

The telecommunications sector is growing at a phenomenal rate in the current era of technological growth. During the last several years, the sector has experienced substantial expansion related to telecommunications projects, which has resulted in the building of many towers to expand the coverage area and network compliance. These towers are crucial to wireless communication networks, hence the collapse of such a building in a catastrophe poses a serious risk. It has been demonstrated in several instances that wind is the primary reason for tower failure. During storms and hurricanes, wind speeds may quickly exceed intended wind speeds. Such a powerful breeze may easily cause physical damage to the structure and this could place a huge economic burden on the organization. Therefore, additional importance should be given to considering all possible adverse conditions for the analysis and design of these towers. Also, recent developments in communications engineering have presented construction engineers with a challenge to the economically viable design of telecommunication towers. Communication towers are usually space frames composed of Pins made of metal parts to hold transmitters and receivers. In addition, earthquake loads are important in the design of these towers. In particular, the metal lattice-type tower, which may be a three-legged lattice tower or a four-legged steel tower, is widely used in the world to support mobile antennas and microwaves because they are ideal for high altitude conditions. Metal lattice towers are usually constructed using the main leg angles and binding elements. The members are assembled together, either directly or by gusset plates. In order to reduce unsupported lengths and thus increase their binding strength, the main legs, and the intermediate support elements are supported between their end nodes, using bracing. Since a single extended tower design can be used for hundreds of

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towers for power transfer and communication purposes, it is very important to find a cost-effective and efficient design. In this project work, a 24 m tall lattice tower is considered and a variety of bracing systems such as K, V, X, and Y are considered the project aims to compare four-legged communication towers with each other. Towers are analyzed and designed using STADD Pro as per IS 800 - 2007, The dead load, the living load, and the wind load operating on the tower are calculated according to the corresponding IS code ie, IS 875-2015 Part 1 (dead load), IS 875-2015 Part 2 (imposed load) and IS 875-2015 Part 3 (Wind load). From this work, it can be concluded that at a certain height of the four-legged communication tower how different types of bracing systems affect the strength, performance, and economy of the tower. The project also aims to determine the best type of bracing system that can provide the most efficient bracing system.

2. PROBLEM STATEMENT

The telecommunication industry has become the backbone of the country without which there would have trouble in all the day-to-day processes which are now on the internet ecosystem. In this sector a major role for the transfer of data and information is done with the help of telecommunication towers only so to facilitate the economy during the construction of tower there is a need to find out a bracing pattern which is economical as well as good in taking load

3. OBJECTIVE OF WORK

• Generate 3D models of a telecommunication tower using STAAD Pro software to carry out analysis and design.

• Study dead load, live load, and wind load acting on the telecommunication tower as per the respective IS code.

• Study the effects of loads on the various bracing systems by analyzing the displacement profile of the tower.

• Determine the most efficient bracing system.

4. METHODOLOGY

In Methodology, all the important aspect and procedures performed during the analysis and design of the tower are included:

It includes the following:

- a) Specification of Tower and Material
- b) Load Calculation
- c) Modeling of Tower on STAAD Pro
- d) Analysis and Design of Tower
- 4.1 Specification of Tower and Material
- Height of Tower: 24 m
- Top Width of Tower: 1.2 m
- Bottom Width of Tower: 4 m
- Site Selected: Pune

• Communication Equipment and Antenna considered: GSM-1 Antenna (2500 mm * 250 mm * 150 mm), GSM-2 Antenna (1500mm * 170 mm * 150 mm) and Microwave Antenna circular (600 mm, diameter = 80 mm)

- Types of Bracings considered: K, V, X, Y
- Type of sections: Angular Section
- Support Condition: Fixed.
- Material used: Steel
- Modulus of Elasticity of steel (Es): 200 GPa
- Poisson's ratio (µs) :0.3
- Density of steel (γsteel): 77 kN/m3 (7.850 kg/m3)
- Yield strength of steel (fy): 415 M Pa



Figure 1: Elevation of Tower and Types of Bracing



Figure 2: Orientation of Antenna

4.2 Load Calculation

The load combinations considered for the study are:

For the Limit State of Collapse

- 1) 1.5 (Dead Load + Live Load)
- 2) 1.5 (Dead Load + Wind Load in X Direction
- 3) 1.5 (Dead Load + Wind Load in Diagonal Direction)
- For the Limit State of Serviceability
- 1) Dead Load + Live Load
- 2) Dead Load + Wind Load in X Direction
- 3) Dead Load + Wind Load in Diagonal Direction
- 4) Dead Load + Operational Wind Load in X Direction

5) Dead Load + Operational Wind Load in Diagonal Direction The calculation of loads is as follows:

a) Dead Load:

The dead loads acting on the structure include the self-weight of the structural elements like bracings and loads of antennas and other equipment used.

For the Study, the types of antennae which has been considered are:

Sr. No.	Description	No	Length (mm)	Width (mm)	Thickness (mm)	Weight (kg)	Total Weight (kg)
1	GSM1 Antenna	3	2500	250	150	25	75
2	GSM2 Antenna	6	1500	170	150	20	120
3	Microwave Antenna (circular)	4	600		•	30	120

JNAO Vol. 14, Issue. 01: 2023 Table 1: Calculation of Dead Load

Total Weight of all equipment's = 75 + 120 + 120 = 315 kg

= 3150 N

= 3.150 kN

b) Live Load or Imposed Load:

Live or imposed loads include the weight of the technicians along with his equipment which is required during maintenance.

The Live considered for this study:

Live Load or Imposed Load = 100 kg

= 1000 N

= 1 kN

c) Wind Load:

The wind load on the tower can be calculated using the Indian standards IS 875 (Part3) 1987. For the study, the region selected in Pune.

Step1: To calculate design wind pressure Design Wind Speed = Vz = K1 * K2 * K3 * Vb Risk Coefficient (K1) = 0.92 for 25 years

Terrain Factor (K2) = 1.10 for 24 m and class B of terrain category 2 Topography Factor (K3) = 1 for the given plain topography

Basic Wind Speed (Vb) = 39 m/s for Pune region Vz=0.92 * 1.10 * 1 * 39 = 39.468 m/s

Design wind pressure = Pz = 0.6 * Vz2 = 1.218 kN/m2

Step2: To calculate wind load on antenna

Wind load on Antenna

= Force Coefficient (Cf) * Design Wind Pressure (Vz) * Area of Exposed Surface Where, Force Coefficient (Cf) can be calculated from IS 875 - 2015 (Part 3) clause

6.3.2.1 figure 6 and table 20

Sr. No.	Descriptio n	Lengt h (mm)	Wid th (m m)	Thickne ss (mm)	Cf	Area (sq.m)	Vz (kN/ m ²)	Wind Force (kN)
1	GSM1 Antenna	2500	25 0	150	1.8	0.625	1.21 8	1.193
2	GSM2 Antenna	1500	17 0	150	1.7	0.255	1.21 8	0.460
3	Microwa ve Antenna (circular)	600	1	2	1.2	0.285	1.21 8	0.360

Table 2: Calculation of Wind Load

Step3: To calculate wind load on tower members Wind load on Tower Members 227 **JNAO** Vol. 14, Issue. 01: 2023 = Force Coefficient (Cf) * Design Wind Pressure (Pz) * Area of Exposed Surface Where, Force Coefficient (Cf) can be calculated from IS 875 – 2015 (Part 3) clause 6.3.3.4(a)

For K bracing,

Wind Load on Members,

ISA 110 x 110 x 8 = 0.272 kN / m

ISA 80 x 80 x 12 = 0.198 kN/ m

For V bracing,

Wind Load on Members,

ISA 110 x 110 x 8 = 0.272 kN / m

ISA 80 x 80 x 12 = 0.198 kN/ m

For X bracing,

Wind Load on Members,

ISA 110 x 110 x 8 = 0.231 kN / m

ISA 80 x 80 x 12 = 0.168 kN/ m

For Y bracing,

Wind Load on Members,

ISA 110 x 110 x 8 = 0.260 kN / m

ISA 80 x 80 x 12 = 0.189 kN/m

Step 4: To calculate the operational design wind pressure

Operational wind load is calculated for checking the deflection of the tower at operation wind speed as it will be subjected to this load for most of its design period.

Operation Design Wind Speed = Vz = K1 * K2 * K3 * Vo Risk Coefficient (K1) = 0.92 for 25 years Terrain Factor (K2) = 1.10 for 24 m and class B of terrain category 2 Topography Factor (K3) = 1 for the given plain topography Operational Wind Speed (Vo) = (2/3) * 39 m/s

= 26 m/s

Vz= 0.92 * 1.10 * 1 * 26 = 39.468 m/s

Operational Design Wind Pressure = Pz = 0.6 * Vz2 = 0.415 kN/m2 Step 5: To calculate operational wind load on antenna Operational Wind Load on Antenna

= Force Coefficient (Cf) * Operational Design Wind Pressure (Pz) * Area of Exposed Surface

Sr. No.	Description	Length (mm)	Width (mm)	Thickness (mm)	<u>Cf</u>	Area (sq.m)	Vz (kN/m²)	Operational Wind Force (kN)
1	GSM1 Antenna	2500	250	150	1.8	0.625	0.415	0.466
2	GSM2 Antenna	1500	170	150	1.7	0.255	0.415	0.179
3	Microwave Antenna (circular)	600		-	1.2	0.285	0.415	0.141

 Table 3: Calculation of Operational Wind Load

Step3: To calculate operational wind load on tower members

Operational Wind load on Tower Members

= Force Coefficient (Cf) * Operational Design Wind Pressure (Pz) * Area of Exposed Surface For K bracing, Operational Wind Load on Members, ISA 110 x 110 x 8 = 0.120 kN / m ISA 80 x 80 x 12 = 0.087 kN/ m For V bracing, Operational Wind Load on Members, ISA 110 x 110 x 8 = 0.120 kN / m 228

ISA 80 x 80 x 12 = 0.087 kN/ m For X bracing, Operational Wind Load on Members, ISA 110 x 110 x 8 = 0.115 kN / m ISA 80 x 80 x 12 = 0.084 kN/ m For Y bracing, Operational Wind Load on Members, ISA 110 x 110 x 8 = 0.102 kN / m ISA 80 x 80 x 12 = 0.874 kN/ m Modeling of Tower on STAAD Pro

The model will be created using the coordinate data for the points and the element connectivity table and suitable cross-sectional properties are to be assigned to the elements created. The boundary condition is to be stimulated in the model by fixing the four lowermost nodes of the modeled structure. The loads calculated above are to be applied at appropriate nodes and the stress parameters, and deformation of the structure under the effect of the applied load is to be studied.

The models of towers are as shown below in the figures:



Fig 3: Modeling of Towers (K,V, X, Y)

4.3 Analysis and Design of Tower

The lattice tower model was analysed in STAAD Pro V8i software. The models which were created using the coordinate data for the points and the element connectivity table is analyzed on various loading condition on STAAD Pro. The loads calculated above are applied at appropriate nodes and the stress parameters, and deformation of the structure under the effect of the applied load is studied.f



Fig 4: Analysis of Towers on STAAD Pro

Suitable steel sections are initially assumed as members of the tower for analyzing the structure. Once the analysis is done members are finalized based on the developing in them, following the codal provisions provided by Indian Standards. 229

- The maximum allowable stresses in the members are given in IS 802 (Part-1).
- Limiting slenderness ratios for members are given in IS 802(Part-1).
- o Allowable Slenderness Ratio for Tension Member = 400
- o Allowable Slenderness Ratio for Compression Member = 180 stresses
- Effective Length of compression members should be assumed as per IS 806(1968).

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Fig 5: Report of Design on STAAD Pro

For comparison purposes, the members which are selected by analyzing the effects of load on the towers were the same for all the towers to get fair information about deflection and other parameters. After analysis and design on Staad Pro the following members were selected:

- Main Legs (4 Numbers): ISA 110 x 100 x 8
- Bracing: ISA 80 x 80 x 12

5. RESULTS AND DISCUSSION

After completion of load allocation and designing, analysis is carried out only for the zone of basic wind speed of 39m/s. The combination of self-weight, antenna load, live load, and wind load is taken for the analysis of models. The displacement profile of the tower is calculated for a load combination of wind load operational wind speed in X-direction and diagonal direction is considered along with the dead load. The graph of deflection along X- direction, Y-direction, and Z-direction concerning the height of the tower are plotted for all the bracing systems along with this graph of resultant displacement concerning the height of the tower is also plotted and the amount of steel required for each type of bracing system is determined and compared.

5.1 Analysis and comparison of Resultant Deflection for all braced towers at Operational Wind Speed

Load condition 1: Dead Load + Operational Wind Load in X-Direction

The graph below shows the resultant deflection at various elevation levels for all the bracing system:



Fig 6: Deflection vs Height of Tower Graph at Operation Wind Speed in X- direction

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Load condition 2: Dead Load + Operational Wind Load in Diagonal Direction The table below shows the resultant deflection at various elevation levels for all the bracing system:





5.2 Determination of Steel Quantity

The total amount of steel required to fully complete the structure is worked out by using the software STAAD Pro. The amount of steel used is represented in the below graph:

Fig 7: Comparison between Steel Quantities for Different Bracing

CONCLUSION

The following specific conclusions can be reached based on research conducted in a variety of ways:

• From the comparison made in case of dead load+ wind load in X-direction load condition it can be concluded that X- bracing system produced minimum deflection at the top which is about 21.220 mm followed by K-bracing, Y-bracing and V-bracing which are producing a deflection of 24.440 mm, 24.675 mm and 28.909 mm.

• In the given case, X-bracing has 15% less deflection as compared to K-bracing, followed by 16% less deflection as compared to Y-bracing and 41% less deflection compared to V-bracing

• Comparison made in case of dead load + wind load in diagonal direction load condition it can be concluded that X- bracing system is again produced minimum deflection at the top which is about 20.621 mm followed by K-bracing, Y-bracing and V- bracing which are producing a deflection of 23.625 mm, 24,193 mm and 27.754 mm.

• From the given case again, X-bracing has 15% less deflection as compared to K-bracing, again 17% less deflection as compared to Y-bracing and 35% less deflection compared to V-bracing

• From the comparison in case of amount of steel required it can be concluded that K- bracing requires 5.009 tonnes of steel followed by V-bracing, X-bracing and Y-bracing which require 5.076 tonnes, 5.629 tonnes and 6.541 tonnes.

• From all the above points it can be concluded that K-bracing is the most suitable type of bracing for design of telecommunication tower.

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