Design of cell transmission tower with different bracing patterns

NAGA SUBRAMANIAN G[1], ARUN K[2] SARAVANAN M[3] SUVAM KARMAKAR[4]

[1]ASSISTANT PROFESSOR,Department of civil engineering,PERI INSTITUTE OF TECHNOLOGY,CHENNAI
[2,3,4]B.E Student,Department of civil engineering PERI INSTITUTE OF TECHNOLOGY,CHENNAI

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Abstract - *The analysis and design of a cell transmission tower employing various bracing designs is the primary focus of this article. Angles are typically used in the fabrication of steel lattice towers for the bracing members and main legs.When a high load bearing capacity, low self weight, economical material usage, and quick manufacturing and construction are required, latticed structures are the ideal option. These factors make self-supporting lattice towers most common in the power line and telecommunications industries. Finding a cost-effective and extremely efficient design is crucial.*

As few members as feasible should be used in the tower's arrangement to maintain its basic geometry, and every member should be sufficiently stressed under several loading cases. The objective is to create an appealing, well-proportioned, and cost-effective building. Towers are built with a high safety factor for wind loads.

Key Word...**Transmission tower, wind speed, analysis, design, staad-pro**

1.INTRODUCTION

India is inhabited to a substantial population that requires an extensive transmission and distribution network in order to meet their needs for energy and signal supply. Angles are commonly employed in the bracing components and main legs of lattice tower construction. Because cell towers, also known as cell sites, are equipped with electric communications equipment and antennae, telephones and radios in the surrounding area may connect wirelessly. Towers are modelled using constants such as height, bracing system, angle sections, base widths, wind zone, common clearances, span, conductor, and ground wire parameters.

Members may be secured by gusset plates or by direct fastening. To reduce the unsupported length and increase their buckling strength, the main legs and the bracing components are laterally supported at intervals between their end nodes using redundant or secondary bracings. Lattice structures are ideal for applications requiring a high load carrying capacity, low self-weight, efficient material utilisation, and speedy manufacture and assembly. The power line and telecommunications sectors are the ones that use self-supporting latticed towers the most due to these considerations. Since hundreds of towers may be utilised for power transmission and communication purposes, it is critical to find an incredibly efficient and reasonably priced lattice tower design.

1.1 Scope of the Study

The primary goals of this study are to build towers with effective bracing patterns and to use appropriate bracing patterns to minimise maximum member stress and frequency. Additionally, to build the tower with a high wind load safety factor.

1.2 Objectives

The goals of this suggested research work are to design a cell transmission tower, including foundation details, and analyse it, taking into account the fundamental factors listed below.

I. Base width II. Height of the tower

III. Soil bearing capacity IV. configuration of tower

The following tasks need to be completed in order to achieve these goals:

a.Tower layouts are created with AUTOCAD.
b. The towers' longitudinal face is used to compute wind load.
c. The loading format and safety pattern need to be assessed
d.The towers are now modelled and examined using STADD.pro as a three-dimensional structure.

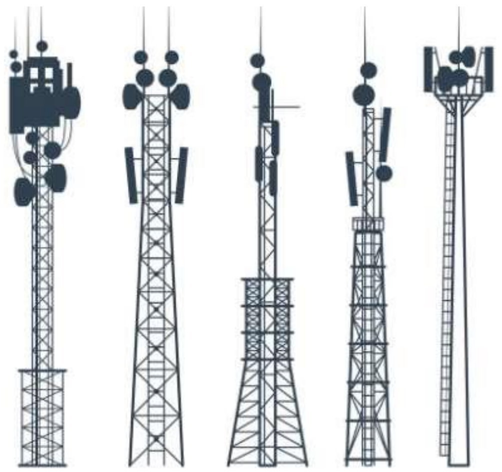


Fig. 1 Different types of Bracing Cell Towers

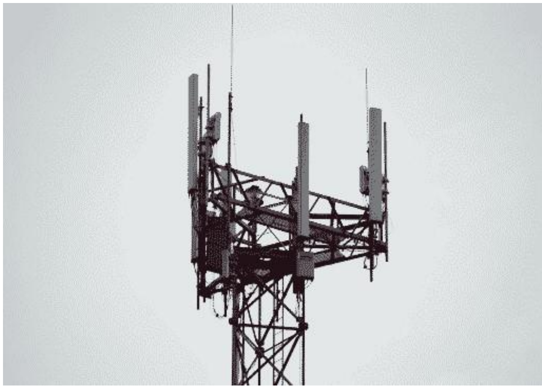


Fig.2 Cell Towers

2. LITERATURE REVIEW

Keshav Kr. Sharma (2015), Three tower heights—25, 35, and 45 meters—are compared in this article for India's seismic zones II through V and wind zones I through VI using different bracing technologies. The gust factor technique is used for wind load analysis, and reaction spectrum analysis and modal analysis are used for earthquake loading. This article concludes that the wind, not seismic forces, is the main component in tower modelling. The results demonstrate that the seismic influence cannot be entirely disregarded, and V-Bracing yields good results for all investigated wind and earthquake zones stated in the IS code when it comes to wind analysis, modal analysis, and response spectrum analysis. The outcomes of displacement at the structures' tops and the strains in their bottom legs

Jithesh Rajasekharan (2014), used the gust factor approach to examine the impact of wind load on a four-legged lattice tower in wind zones V and VI. Three distinct heights of the lattice tower were constructed, using different types of bracings, at 30, 40, and 50 metres. In order to investigate the seismic impact on the tower structures, they also carried out reaction spectrum analysis and modal analyses for zones II through V. They concluded that the member stresses in the bottom leg of the XX braced tower are higher than in other tower types. The tower with Y bracing had the lowest natural frequency among the models since it was found that its stiffness was higher because the structure was heavier than the other models. From 30 to 40 metres above the ground, the displacement increased almost linearly, but as the height rose from 40 metres to to 50m there is a steep increase in the displacement in all the Zones

Gopi Sudam Punse (Transmission Tower Analysis and Design) This thesis examines the analysis and design of a narrow-based transmission tower in India that uses multivoltage multicircuit technology, with the goal of maximizing electrical supply usage given the available ROW and the area's expanding population. About 28–42% of the total cost of the cables is made up of transmission line towers. One of the most cost-effective ways to meet the increasing demand for power is to create various lightweight transmission tower layouts. In this project, an effort has been made to shape the cable in a more cost-effective manner while keeping in mind the unique transmission tower construction that will provide the best possible electric supply for the designated region.The target of this research is met by choosing a 220KV and 110KV Multi Voltage Multi Circuit with narrow based Self Supporting Lattice Towers with a view to improve the prevailing geometry. Using STAAD PRO v8i analysis and style of tower.

Jesumi.et al. (2013),The purpose of this study was to simulate five steel lattice towers for a certain height range using various bracing configurations, including the X-B, Single diagonal, XX, K, and Y bracings. The towers have a base width of 2 meters and a height of 50 meters, respectively. Thirteen panels make up the 40-meter tower, while sixteen panels make up the 50-meter tower. The tapering section of the tower requires 70–72% of its height, whereas the straight section requires 28–30% of its height. Using STAAD Pro V8i, the towers' wind loads were examined in order to compare the maximum joint displacement of each tower. Optimized design has been carried out to estimate and to compare the weight of each tower. From the results obtained, Y bracing has been found to be the most economical bracing system up to a height of 50 m.

Y. M. Ghugal , U. S. Salunkhe (2011) The most typical application for four-legged lattice towers is as transmission line towers. Three-legged towers are not utilized as transmission line towers in the power industry; instead, they are exclusively utilized for radio, microwave, and telecommunication purposes. An attempt is made in this research to build the three-legged towers as transmission line towers with twin circuits at 400 KV. In the current study, two self-supporting 400 KV steel transmission line towers—three- and four-legged models—are analyzed and designed utilizing standard criteria including constant height, bracing system, and angle section system. According to IS: 802 (1995), continuous loading characteristics, including wind forces, are included in this analysis.After analysis, the comparative study is presented with respective to slenderness effect, critical sections, forces and deflections of both three legged and four legged towers. A saving in steel weight up to 21.2% resulted when a three legged tower is compared with a four legged type.

Balaji Patil, K.S.Upase Prof. Hamne A,This study focuses on the Estimation of a feasible transmission line tower for different wind speed by designing transmission line tower with hot rolled sections and compare three types of bracings. For this purpose, 220 kV double circuit selfsupporting transmission towers having square base is used. Analysis of this transmission tower is carried out using STAAD PRO subjected to wind load for Zone-II, III and IV. Load calculation for the analysis is carried out according to IS 802:1995. Finally, the optimal design of transmission tower using hot-rolled steel is compared for wind speed.

V. Lakshmi, A. Rajagopala Rao,This paper looks at the performance of the 132-kV, 21-meter tower in a medium wind setting. The basic wind speeds, the impact of terrain and altitude above the ground, design wind speed, design wind pressure, and design wind force are all fully explained, as are the IS 875-2007 guidelines. The performance of the tower is evaluated, along with the member forces in the vertical, horizontal, and diagonal members. Three distinct groups are identified along with their key elements. The next chapters evaluate the tower's performance under atypical situations, such as isolated malfunctions. The finer aspects of analysis, load calculation, and modelling are covered. Point loads and loads imposed at panel joints are derived from the strength of the wind.

N.PrasadRao et.al(2011),To keep the transmission system reliable and secure, it is imperative to predict tower failures precisely because they are integral components of transmission lines. Significant direct and indirect losses are incurred by failure, in addition to additional costs for power interruptions and legal fees. The presentation discusses the many types of early failures observed during full-scale testing of transmission line towers at the Tower Testing and Research Station in Chennai, which is operated by the Structural Engineering Research Centre. Testing-related failures are analysed and their causes are addressed in depth.The impact of isolated hip bracings linked to elevation redundancy in "K" and "X" braced panels, as well as non-triangulated hip bracing pattern, on tower behaviour is investigated.The elements of the tower are modelled as beams, columns, and plates. Using finite element software, different failure modes are simulated, and test and analytical findings are compared with different codal provisions. Tower elastoplastic behaviour is modelled using NE-NASTRAN, a broad purpose finite element analysis software. It is emphasised how crucial redundant member design and connection details are to the tower's overall performance.

G.Visweswara Rao"OPTIMUM DESIGNS FOR TRANSMISSION LINE TOWERS" Senior research Analyst, Engineering Mechanics Research India, 907 Barton Centre Bangalore .The following findings were covered in this study.The study presents a process for creating optimised tower designs for additional high-voltage transmission lines. Both tower weight and geometry are taken into consideration during optimisation. It is accomplished by managing a selected group of important design factors. The design process also incorporates some degree of fuzzy specification for these control variables. The programme includes a derivative-free nonlinear optimisation approach that was created specifically for the configuration, analysis, and design of transmission line towers. A few intriguing outcomes of both fuzzy and crisp optimisation that are pertinent to the common double circuit transmission line tower under multiple loading condition, are presented.

3.METHODOLOGY

The selected area for our study is rich in red soil as well as peaty soil. Red soil present in the selected region possesses lower strength compared to other soils due to its porous and friable structure. Madurai zone located in wind zone III The basic wind speed in this region is considered as 39 m/sec according to IS 875:2007

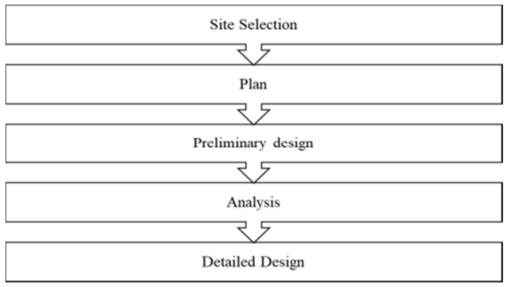
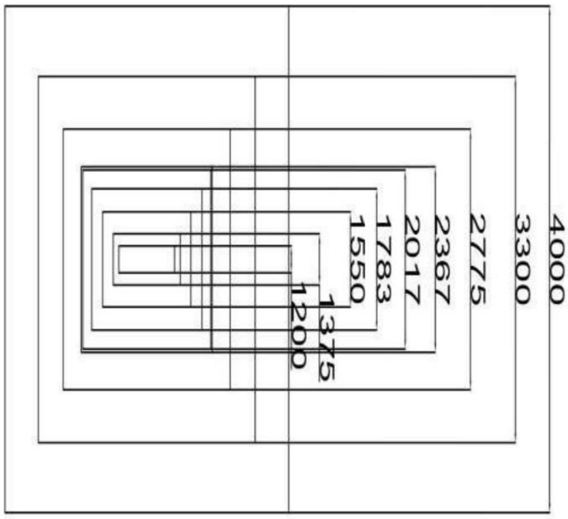


Fig. 3.1Methodology plan

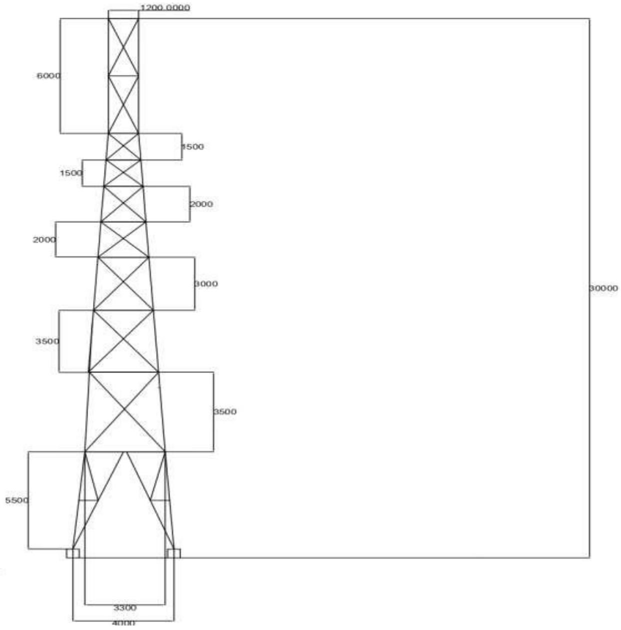


[All dimensions are in mm]
Fig 3.2 Top View

3.1 CONFIGURATION OF THE TOWER:

Communication Tower, like any other exposed structure, has a super structure shaped, dimensioned and designed to suit the external loads and self- weight Selection of configuration of a tower involves fixing of top width, bottom width, number of panels and their heights, type of bracing system and slope of tower. The following are key parameters in configuration of tower.
a. Width at bottom level = 4 m
b. Width at top level = 1.20 m
c. Overall height = 30 m
d. Number of levels = 9 levels
e. Slope of outline tower = 87 degree

Fig 3.3 Transmission Tower



[All dimensions are in mm]

Fig 3.4Cross sectional View

Different bracing patterns are provided along with the different levels and height of the tower

3.2 LOAD CONSIDERATIONS:

For communication towers, the tower's self-weight is the most crucial aspect of its design. Even though the telecommunication steel tower is a light construction with pin joints, people nevertheless perceive that it behaves like a straightforward truss. Although wind loads operating on the tower will be smaller than those acting on chimneys since the tower construction will have more than 30% of openings, high intensity winds (HIW) continue to be the primary cause of communications tower failures worldwide. Since wind loads are estimated using a probabilistic methodology, the main issue is how difficult it is to do so. Numerous studies on telecommunication towers have taken into account both the dynamic effect and the wind.

The loadings which are considered during this study are:

Dead loads or Vertical loads

1. Self-weight of tower members

2. Self-weight of antennas

3. Load due to labour and equipment during construction and maintenance

a. Wind load on exposed members of the tower and antenna.

b. Wind load on tower: It can be calculated using the Indian standards IS: 875(Part 3) to 1987[3] and BS: 8100 (Part 1)-1996[4].

c. Wind load on antennae: The wind load on antennas should be calculated using Andrew's catalogue. The wind loads on antennas are listed in the Andrew's catalogue at wind speeds of 200 kmph. The antenna loads must be determined by the designer in accordance with the specified wind speed.

Table 1:Bracing pattern

LEVELS	HEIGHT	BASE WIDTH	BRACING PATTERN		
			TYPE I	TYPE II	TYPE III
0	0	4	K2 BRACE DOWN	K2 BRACE DOWN	K2 BRACE DOWN
1	6	3.3	XX	V	K
2	10.6	2.775	XX	V	K
3	14	2.367	XX	V	K
4	17	2.017	XX	V	K
5	19	1.783	XX	V	K
6	21	1.55	XX	V	K
7	22.5	1.375	XX	V	K
8	24	1.2	XX	V	K
9	30	1.2	XX	V	K

3.3 DESIGN WIND PRESSURE:

Based on the wind speed map the entire country has been divided into six wind zones with max. wind speed of 55 m/sec. and min. wind speed of 33 m/sec. Basic wind speeds for the six wind zones are

Wind Zone Basic Wind Speed (m/sec)

1 33

2 39

3	44
4	47
5	50
6	55

At Madurai region the design wind speed = 39m/s

Design speed at the site (Vz) = K1*K2*K3*Vb

Risk coefficient (K1 for 100years life) = 1.0

K2, Terrain factor for 30m and class B for Terrain category =1.3

Topography factor[K3] = 1+Cs

For the given plain topography K3 = 1[As C=0]

Vz = 1.08×1.03×1.39 = 55.62 m/s

HEIGHT	DESIGN WIND PRESSURE(KN/m²)
0	0
10	1.36
12	1.44
15	1.55
18	1.63
21	1.70
24	1.75
27	1.81
30	1.86

4.A NALYSIS&DESIGN

The STAAD Pro software programme was used to examine the lattice tower model. The coordinate data for the points and the element connection table were used to generate the model, and the elements were given appropriate cross-sectional characteristics. By establishing the three lowest nodes of the simulated structure, the boundary condition was triggered in the model. The aforementioned loads are applied at the proper nodes, and the stress parameters and structural deformation caused by the imposed load are examined.

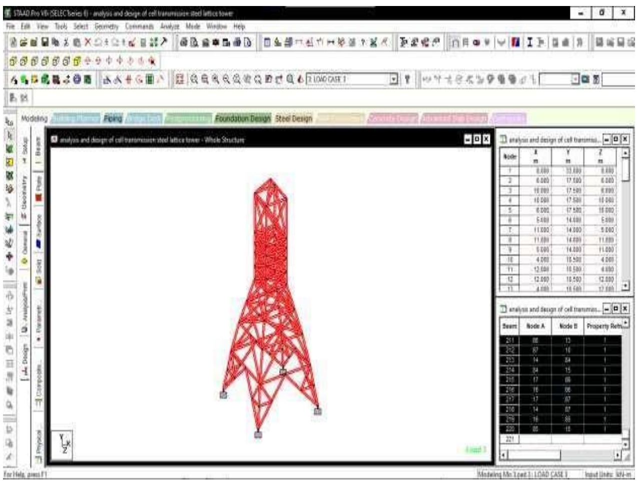


Fig 4.1 X-X Bracing Tower-Nodal Analysis

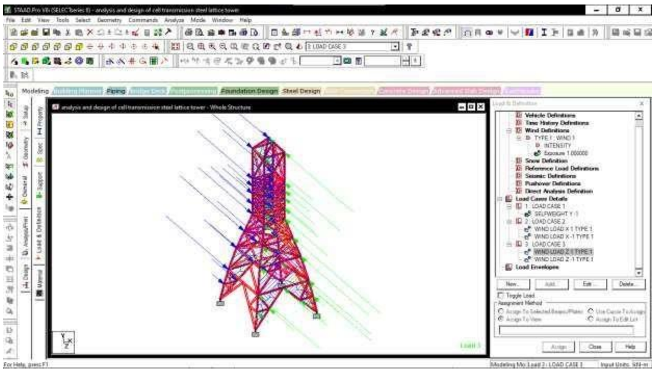


Fig 4.2 Bracing Tower- Wind Load Analysis

4.1DETAILED DESIGN

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

1. The maximum allowable stresses in the members are given in IS 802 (Part-1).

2. Limiting slenderness ratios for members are given in IS 802(Part-1).

3. Effective Length of compression members should be assumed as per IS 806(1968)

Connect base plate to foundation concrete using 4 Numbers of 20mm diameter and 300mm long anchor bolts.

If weld is to be used for connecting column to base plate check the weld length of filler weeds.

4.2 DESIGN OF FOUNDATION

The raft foundation is selected for this tower. Since the soil is under consolidated to about 5-8 m depth, it was decided to improve the ground and bearing capacity of the soil. Therefore, raft foundation is selected for this structure

4.3 DESIGN OF BASE SLAB

As per IS 800:2007,

Bearing strength of concrete = 0.6fck

But for practical consideration bearing strength = 0.45fck

∴ Area of plate required = $(P_u)/0.45f_{ck}$

Where Pu = Factored load

Load on each leg is = 400KN

Factored load on each leg = 600KN

Area of plate required = (600) / (0.45×25)

= 53333.33 mm2

∴ Side of each base plate = 300 × 300 mm2

Minimum thickness required [ts] =
$(2.5w(a2-0.3b2)\gamma mo\ f_y)0.5$

Where W = P_u ×area of base plate = 600×1000 300×300

= 6.66 N/mm2

a = 95 mm and b = 95 mm

ts = (2.5×6.66 × (952−0.3×952) m × 1.1250).

∴ ts =25 mm

(As ts > tf (truss angle thickness ts = 12mm), hence safe.)

Connect base plate to foundation concrete using 4 Numbers of 20mm

diameter and 300mm long anchor bolts.

If weld is to be used for connecting column to base plate check the weld

length of filler weeds.

4.4DESIGN OF RAFT FOUNDATION

Initially assume footing size = 5m × 5m

Uniform load on footing (W) = axial load area

= 800 * 25 = 32 KN/m2

Consider per meter width then load is = 32 KN/m

Maximum bending moment at centre of footing = 100 KNm

Bending moment required Mu = 0.138fckbd2

100×106 = 0.138 × 25 × 1000 × d2

= 170.25 mm

∴ d = 200 mm.

4.5Area of steel required

Mu = $0.87\ f_y A_{st}\ d\ (1\text{-}\ A_{st}\times f_y\ bd\times f_{ck})$

100×106 = 0.87×415×Ast×200× (1- A_{st}×415 1000×200×25)

Assume concrete grade = M20

Steel grade = Fe415

Ast required = 1596.36 mm2

Assume diameter of bars = 12 mm

No. of bars required = 1596.36 (4)×122 = 15 bars

Spacing of bars = 5000 /20 =250 mm

∴ Provide 20 bars of 12 mm dia 250 mm cc on both sides.

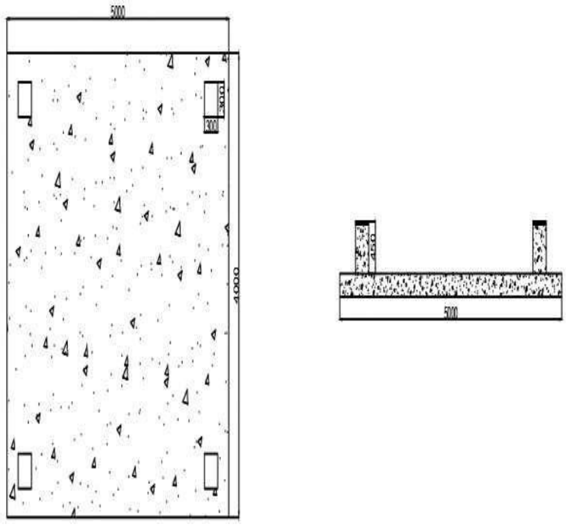


Fig 4.3 CROSS SECTIONAL VIEW

4.6 MODELING AND ANALYSIS

STAAD Pro V8i was used to assess the lattice tower model. The coordinate data for the points and the element connection table were used to generate the model, and the elements were given appropriate cross-sectional characteristics. Fixing the three lowest nodes of the simulated structure activated the boundary condition in the model. The previously described loads are applied at the proper nodes, and the stress parameters and structural deformation caused by the imposed load are examined.

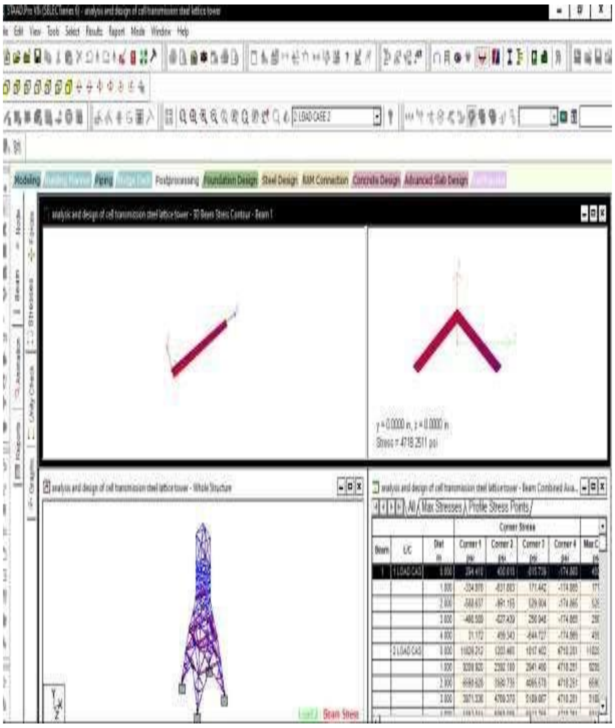


Fig 4.4X-X Bracing Tower-Bending Stress Analysis

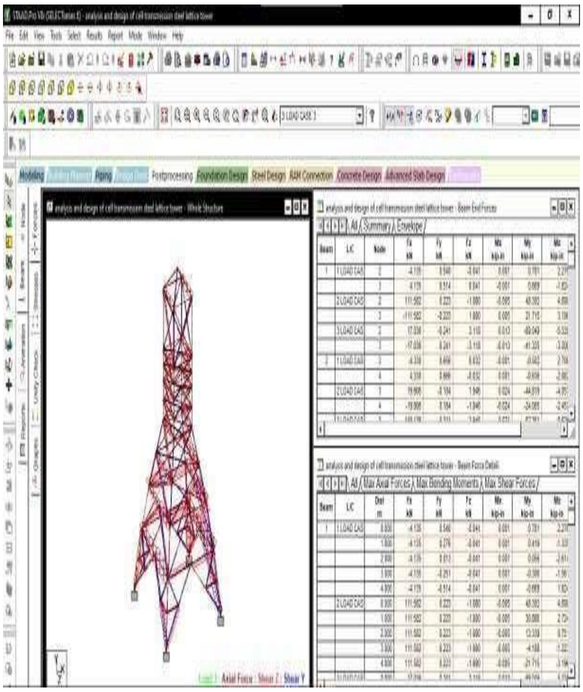


Fig 4.5X-X Bracing Tower- Shear Stress Analysis

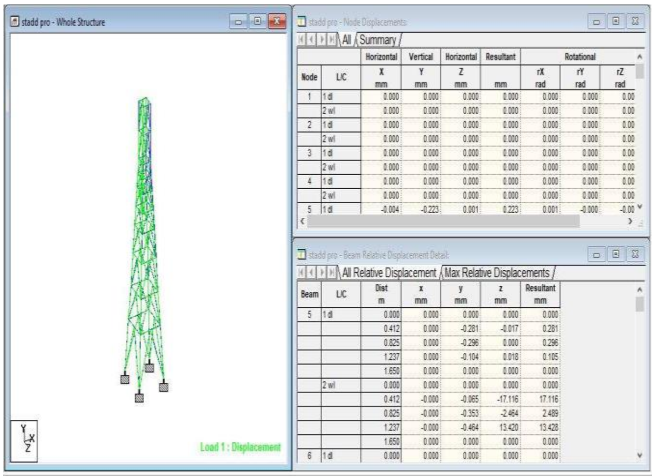


Fig 4.6 V bracing tower –Displacement Values

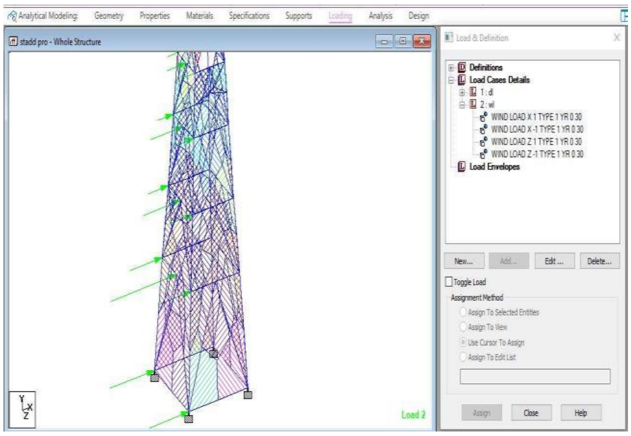


Fig 4.7V bracing tower –Wind Loading

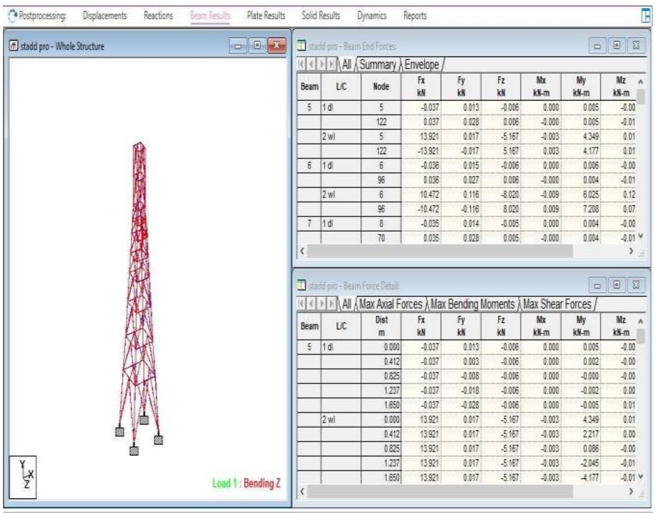


Fig 4.8 V bracing tower –bending Values

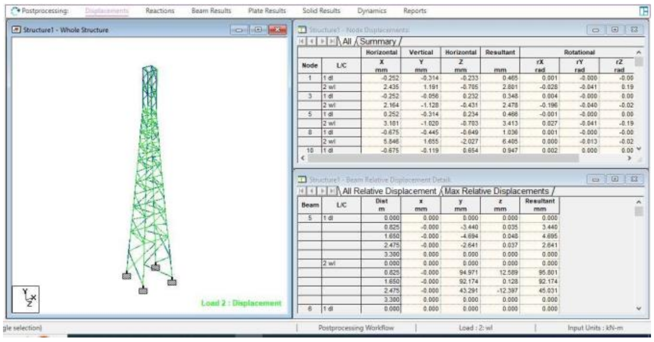


Fig 4.9 K bracing tower –Displacement Values

5. RESULTS &CONCLUSIONS

A Telecommunication tower of 30m high is analysed and designed.

a. The configuration of the tower is as follows:

1. Height of tower = 30m

2. Base width = 4m

3. Top width = 1.2m

4. Type of tower = Four-legged lattice tower with two slopes.

5. Number of members = 184

6. Number of joints = 61

Design has been done according to IS: 802 using STADD.Pro and following results are obtained,

1.Total weight of steel required in superstructure = 327.593 kg.

c. Raft foundation of 5m x 5m has been designed along with slab base and column base to transfer the loads to raft. The details of foundation are:

1. Allowable Bearing Pressure = 250 KPa

2. Thickness of slab base = 25 mm c/c

3. Thickness of column base = 450 mm

4. Thickness of Raft foundation = 22 m

Response spectrum analysis shows that, in comparison to other tower models in the order of K-bracing and V-bracing, the XX-bracing tower joint displacement at the top and maximum member stresses were lowest. Additionally, the modal analysis showed that the V bracing tower has the lowest frequency, followed by K-bracing, XX-bracing, and so on. This suggests that the tower's weight has an impact on the frequency. The XX-bracing tower model was shown to have higher average tensile stress but lower average displacement, compressive stress, and base shear than the K-bracing tower model in both cases.For the XX-bracing model to have gotten three of its four effects lesser than that of the K-bracing, this is an indication that it will perform better than the K-bracing model.

Additionally, since lower frequency depends on both weight and stiffness, the high frequency in the XX bracing model may be decreased by making the members larger. Due to their open design and numerous openings, telecommunication towers are subject to relatively small wind loads; yet, high intensity winds are the primary cause of tower failure. Wind loads should be given a high factor of safety.

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