Analysis and Design of Telecommunication Lattice Tower with Antennas using Different Codes

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Abstract- The paper describes analysis, design and comparison of wind load calculation on lattice tower with IS875 (PartIII) - 1987 wind load standard & design as per IS800-2007& IS802-1992. Steel lattice tower of height 40m considered at rural area with open terrain. The design wind speed and other wind properties as per IS875 considered for analysis. The comparison of different coefficients and loads were prescribed and Comments on the difference are given. Using STAAD PRO V8i analysis and design of tower has been carried out as a 3 dimensional structure then the tower members are designed.
Indian standard: IS-800-2007

Indian standard: IS-802-1992

Keywords- Analysis and design of Steel lattice Tower, IS codes, Towers, STAAD Pro.

I. INTRODUCTION

In the present era the technology in communications has developed to a Very large extent, the faster growth demands advances in the design and Implementation of the communication towers. There are different types of communication towers present now-a-days in the cellular business. The present paper covers the issues related to the types of towers, code provisions for the communication towers, foundation design of the green field. Telecom industry in India is one of the most successfully running sectors due to increasing demand and lot of potential that offers great scope for functioning and further expansion.

Two major factors responsible for growth of telecommunications industry are use of modern technology and market competition. The use of mobile networks has been the crucial reason why the leading companies are showing their interest to invest in Telecommunications industry. The transmission and telecommunication towers design are not a straightforward process, but an interactive compromise between many factors, which must ultimately satisfy basic strength requirements. The design of transmission and telecommunication towers in this slenderness range is very competitive aiming on lower global costs and higher quality issues. Latticed structures are ideally suited for situations requiring a high load carrying capacity, a low self-weight, an economic use of materials, and fast fabrication and construction. For these reasons self-supporting latticed towers are most commonly used in the field of telecommunication and power line system. Because one latticed tower design may be used for hundreds of towers on a power transmission and communication purposes, it is very important to find an economic and highly efficient design. The arrangement of the tower members should keep the tower geometry simple by using as few members as possible and they should be fully stressed under more than one loading condition. The goal is to produce an economical structure that is well proportioned and attractive. Steel lattice towers are usually fabricated using angles for the main legs and the bracing members. The members are bolted together, either directly or through gusset plates. In order to reduce the unsupported length and thus increase their buckling strength, the main legs and the bracing members are laterally supported at intervals in between their end nodes, using secondary bracings or redundant. In order to mitigate the extreme loading conditions due to wind load and icing, study on retrofitting of tower structures is of great significance and urgency. Steel angles are commonly used as members in the construction of tower. Due to the asymmetry of member cross sections, the stability of these angle members would be a complex issue.

II. RELATED STUDY

Types of telecommunication Towers:

The different types of communication towers are based upon their Structural action, their cross-section, the type of sections used and on the Placement of tower. A brief description is as given below: Based on structural action,

Towers are classified into three major groups based on the structural Action, they are:

i) Self-supporting towers ii) Guyed towers iii) Monopole.

Based on cross section of Tower:

Square, Rectangular, triangular, delta, hexagonal and polygonal towers Open steel lattice towers make the most efficient use of material and enable the construction of extremely light-weight and stiff structures by offering less exposed area to wind loads. Most of the power transmission.

Telecommunication and broadcasting towers are lattice towers.

Triangular Lattice Towers have less weight but offer less stiffness in

Torsion, with the increase in number of faces, it is observed that weight of tower increases. The increase is 10% and 20% for square and hexagonal cross sections respectively. If the supporting action of adjacent beams is considered, the expenditure incurred for hexagonal towers is somewhat less.
Based on the sections used for fabrication, towers are classified into Angular and hybrid towers (with tubular and angle bracings)

REQUIREMENT OF TOWER:

A. General requirement:

Shape of the member should be convenient for protection against corrosion, dust, rain etc., and to suit service conditions.

B. Fabrication requirement:

The elements should be simple in shape with minimum number of welds or rivets or bolts and it should be easy to assemble.

C. Erection requirement:

The dimensions of a member must be within the clearance limits of the railway wagon or any transport used.

D. OBJECTIVES OF TOWER:

The objectives of this project is to design a Telecommunication tower, along With foundation details, and to analyze it, below mentioned basic parameters considered:

- Base width
- Height of Tower
- Soil Bearing capacity
- Configuration of Tower.

To meet these objectives the following work has to be done:

- Type and Tower configured with keeping in mind all field and structural constrains are to be followed.
- Loading format including reliability, security and safety pattern are be evaluated.
- Wind loading is calculated on the longitudinal face of the towers.
- Now all the Towers are modelled and analyzed as a three dimensional structure using STAAD pro.
- Finally tower members are designed as an angle section

CODES REFFERED FOR TOWER DESIGN:

Wind load IS 875 Part 3-1987
Angle section:
Design IS 800-2007& 802-1992
Section properties IS 808
Pipe sections:
Design IS 806
Section properties IS1161:1979
Steel MS and HT: IS 2062:1999
Bolts IS2472 (4.6, 5.6 grade)
IS 1367 Part-III, IS 4000

CODE PROVISIONS FOR TELECOMMUNICATION TOWER:

The following are the steps involved in design of communication tower.

- Selection of configuration of tower
- Computation of loads acting on tower
- Analysis of tower for above loads
- Design of tower members according to codes of practices.

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.

- Wind load on tower as per
- Indian standard (875/Part-III)
- Wind load on antennae:

Wind load on antennae shall be considered from Andrew's catalogue. In the Andrew's catalogue the wind loads on antennas are given for 200kmph wind speed. The designer has to calculate the antenna loads corresponding to design wind speed.

GEOMETRY AND COMPONNENTS OF TOWER

Different parts of components of Tower:

Body Members:
a) Main legs, b) Diagonals,
c) Horizontals d) Redundant
e) Ladder, f) Cables g) Platforms

III. ANALITYCAL STUDY

Configuration:

A communication tower, like any other any exposed structure, has a super structure shaped, dimensioned and designed to suit the external loads and self-weight. Selection of configuration of 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.

- Tower height- 40m
- Wind speed- 120 KMPH
- Antenna configuration-
- 3nos 1.2m dia MW Andrew's (solid dish with radome) at 5m from top
- 6nos 0.9m dia MW Andrew's (solid dish with radome) at 10m below from top
- 4nos.GSM(size:2.58X1.50mX0.116m)At 5m top
- 6nosGSM(size:1.5X0.25mX0.116m) at 2.5m below from top
- Cables- One no. of 10mm dia. Cable for each MW antenna and two 22mm dia. for each GSM antenna

Setting criteria:

- Wind Data:
- Basic wind speed- 44m/s (for Hyderabad)
- Terrain category- 2 and Class B
- Mean probable life- 50 years

- Probability factor-1
- Topography Factor- 1

Tower geometry- 4 Legged (square) angular:

- Cross section- Square based angular tower
- Bottom width-6.112m c/c
- Top width-1.8m b/b
- Top vertical portion

Material:

- Steel-

All steel members shall confirm to Mild steel material as per IS: 2062-200

Minimum yield stress 350 Mpa
Allowable bearing stress 500 Mpa

- Bolts-

All structural bolts shall confirm to 5.6 grade as per IS: 12427-2000

Minimum yield stress 310 Mpa
Allowable bearing stress 620 Mpa

Details of ladder arrangement:

Climbing ladder details:

- Width- 400mm
- Legs- L45x45x4
- Rung- 16 dia solid round at 300 mm c/c
- Safety rings- F40X4 @ 1200 c/c
- Vertical flats- F40X4 (3 Nos)
- Cable tray details- width 400mm

Flat F40X5 with at 800mm c/c

Access ladder and cable ladder provided inside along the centreline of tower.

Platform:

- Resting platform considered at 7.5m level
- Optional internal working platform considered at 1.5m level from top

Design standards:

- IS 875 (Part3) :1987 for wind load calculation
- IS 800 & 802 (Part 1- sec2) for design
- IS 808:1989 for properties of angle section
- Factor of safety- 1.5 for angle section
- Tower twist and sway- ±0.5 at 75% of basic wind speed

Load in tower is calculated in two directions:

- 0 degree
- 45 degree

Load combination for tower design:

- Dead load + zero degree direction basic wind speed
- Dead load + 45 degree direction basic wind speed
- Dead load + zero degree direction operational wind speed
- Dead load + 45 degree direction operational wind speed
- Operational wind speed is taken as 75 of basic wind speed

LOAD CONSIDERATIONS:

In case of communication tower wind load is the most important component of tower design. The telecommunication steel tower pin jointed light structure. It is still assumed that their behaviour is similar to simpler truss.

The percentage of openings in towers structure will be more than 30%, so wind loads acting on the tower will be of less magnitude compared to chimneys, but the major cause of failures of telecommunication tower throughout the world thought still remains to be high intensity winds (HIW).

The major problem faced is the difficulty in estimating wind loads as they are based on a probabilities approach. There have been several studies in telecommunication towers taking into consideration the wind as well as dynamic effect.

The loadings which are considered during this project are:

- Dead load or vertical loads:

(I.e. Self-weight of the tower members, Self-weight of antennas, Labour and equipment during construction and maintenance

- Dead load or vertical loads:

(Wind load on exposed members of the tower and antenna)

- Wind load on Tower:

The wind load on tower can be calculated using the Indian standards IS: 875(Part 3)-1987

The designer should select the basic wind speed depending on the Location of tower. The design wind speed is modified to induce the effect of risk factor (K1), terrain coefficient (K2) and local topography (K3) to get the design wind speed

Vz. (Vz = K1*K2*K3*Vb).

The design wind pressure Pz at any height above mean ground level is 0.6Vz2.

The coefficient 0.6 in the above formula depends on a number of factors and mainly on the atmospheric pressure and air temperatures.

Solidity ratio is defined as the ratio of effective area (projected area of all the individual elements) of a frame normal to the wind direction divided by the area enclosed by the boundary of the frame normal to the wind direction.

Force coefficient for lattice towers of square or equilateral triangle section with flat sided members for wind blowing against any face shall be as given in Table 30 of IS:875(Part-3)-1987. Force coefficients for lattice towers of square section with circular.

Members and equilateral triangle section with circular members are as given in tables 31 and 32 of IS: 875(Part-3)-1987 respectively.

Table 2 of IS:875(Part-3)-1987 gives the factors to obtain design wind speed variation with height in different terrains for different classes of structures such as class A, class B, class C.

The wind load acting on a tower can be computed as F= Cf*Ae*Pz*

Where
F = Wind load acting on a Tower
Cf = Drag Coefficient
Ae = Effective projected area
Pz =Wind pressure

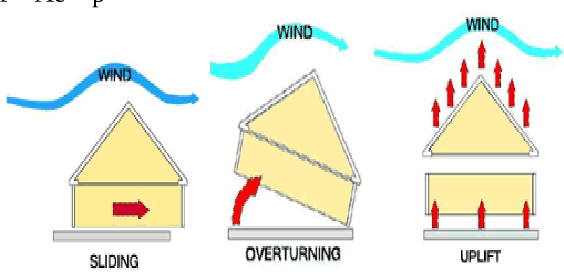
For circular sections the force coefficient depends upon the way in which the wind flows around it and is dependent upon the velocity and kinematic viscosity of the wind and diameter of the section. The force coefficient is usually quoted against a non-dimensional parameter, called the Reynolds number, which takes account of the velocity and viscosity of the medium and the member diameter.

On a latticed structure like tower the following types of wind forces act

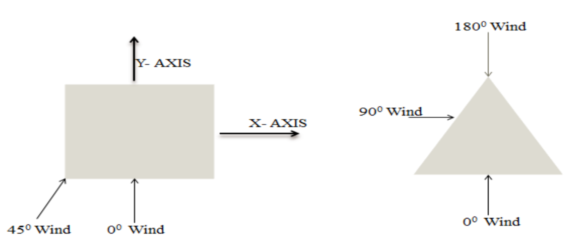
- Vertical uplift
- Downward thrust
- Drag force

The wind load (F) acting on a structure is the product of the wind pressure (p) multiplied by the overall drag coefficient (Cf) times the effective frontal area (Ae) of the structure.

F= Cf * Ae * p



Wind effects



Wind directions

MODELLING AND ANALYSIS:

The tower model was analyzed in STAAD.PRO V8i Software package. The model was created using the coordinate's data for the point and element connectivity table and suitable cross sectional properties were assigned to the elements created. The boundary condition was simulated in the model by fixing the three lowermost nodes of the modelled structure. The loads calculated above are applied at appropriate nodes and the stress parameters; deformation of the structure under the effect of the applied load is studied.

DESIGN OF TOWER MEMBERS:

According to the clause 5.1 of IS 802-Part-I/Sec 2-1992the estimated tensile stresses on the net effective sectional areas in various members shall not exceed minimum guaranteed yield stress of the material. However in case the angle section is connected by one leg only, the estimated tensile stress on the net effective sectional area shall not exceed Fy, where Fy is the minimum guaranteed yield stress of the material. For structural steels confirming to IS-2260 and IS-2062, the yield strength is 350 MPa. Generally yst25 grade tubes confirming IS-1161 is used for tower members. As per IS-802 part1/sec2 estimated compressive stresses in various Members shall not exceed the values given by the formulae in
Clause 5.2.2 of

IS 802-Part-I/Sec 2-1992code.

Limiting slenderness ratios:
The slenderness ratio (l_0/r) of each member is calculated. The ratio is used as a means as assessing the stability of the element.
Based on the curve numbers the (kl_0/r) value is found out. So the allowable stress (kg/cm^2) on the cross sectional area is calculated.
The actual stress (kg/cm^2) on the panel is calculated by dividing the force (kg) acting in the member with the cross sectional area (cm^2).
STRESS RATIO =
ACTUALSTRESS/ALLOWABLE STRESS
As per clause 6.3 of IS-802(Part1/sec2)-1992 the limiting values: KL / r shall be as follows:

Leg members 120
Redundant members and those carrying nominal stresses 250
Other members carrying computed stresses 200
As per clause 6.4 of IS802 (Part1/sec2) Slenderness ratio L / r of a member carrying axial tension only, shall not exceed 400. Similarly for tubular sections as per clause 6.4.2 of IS-806-1968[9] – The ratio of effective length (l) to the appropriate radius of gyration(r) of a Compression member shall not exceed the following values.
Carrying loads resulting from dead loads and superimposed loads-180

Carrying loads resulting from wind or seismic forces only provided the deformation of such members does not adversely; affect the stress in any part of the structure-250

Normally acting as a tie in a roof truss but subject to possible reversal of stress resulting from the action of wind-350

As per clause 6.4.1 of IS-806-1968 the effective length (l) of a Compression member for the purpose of determining allowable axial stresses shall be assumed in accordance with table 7 of IS-806-1968. As per clause 7.2 of IS-802(Part1/sec2) Gusset plates shall be designed to resist the shear, direct and flexural stresses acting on the weakest or critical section. Re – entrant cuts shall be avoided as far as practical. Minimum thickness of gusset shall be 2mm more than lattice it connects only in case when the lattice is directly connected on the gusset outside the leg member. In no case the gusset shall be less than 5mm in thickness.

IV. RESULTS AND DISCUSSIONS

The purpose of this paper is to Analysis and design of steel telecommunication lattice towers by using two different Indian standard codes. Comparative analyses were carried out for same tower heights using same configuration of patterns and steel profiles. An elastic 3D tower model was used to determine the axial forces and stresses in each member under wind and various antenna load cases. Strength and serviceability limit states were controlled according to IS800-2007 and IS-802-1992during design stage.

Failure Modes:

The final Stress ratios and member's forces, joint displacement and weights are the significant parameters obtained from the analysis. However From the results obtained, IS802-1992code of Indian practice has been found to be the most economical design for bracing system up to a considered height of 40m.

Comparison of Results:

Performance-based Wind Engineering is a novel design philosophy that aims to identify and quantify the uncertainties involved in structural design, in order to ensure predictable performance levels to engineering structures. Due to the recent proposal of the methodology and formulation complexity, there are few studies related to PBWE, each presenting different limitations. This paper proposes an application of the Performance-based Wind Engineering methodology to the probabilistic analysis of steel towers, evaluating different calculation models for the estimation of wind forces on this type of structure. Uncertainties involved in the characterization of the wind field and the structural strength were investigated, and two procedures of the Indian standard IS-800-2007 & 802-1992 for the estimation of member forces on steel towers were analyzed. A case study concerning the reliability estimation of a telecommunication tower was also conducted. It was found that both studied calculation models lead to similar safety levels, and that the design of towers considering that wind always blows from the worst direction is too conservative.

V. CONCLUSIONS

The final Stress ratios and member's forces, joint displacement and weights are the significant parameters obtained from the analysis. However. From the results obtained, IS802-1992code of Indian practice has been found to be the most economical design for bracing system up to a considered height of 40m.

VI. FITURE STUDY OF THE SCOPE

- The frame model considered here is as three-dimensional structure model and the same can be proceeding further also.
- This analysis and design is considered for 15 sqm. Antenna area of loading. It can be proceed for more loading also by adding strengthening of the members.
- A further study also includes the camouflaged and alternate solutions for antennas
- Strengthening Solutions may include adding members to the main and proceeding further also
- The frame model considered here is as three-dimensional structure model and bracing members, by reducing slenderness ratio and increasing cross section area (B/B or Star leg connections).
- Alternate solutions include replacing existing X bracing system to single lacing system which will give more additional sharing Area

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