Behaviour of Self-Supporting Communication Tower Subjected to Wind Load

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Abstract: ***The main objective of the Project is the "Behaviour Of Self-Supporting Communication Tower Subjected To Wind Load" The thesis deals with the study of the behaviours of self supporting tower under static and dynamic loading cases. The study is extended for the behaviour of tower in both face and corner wind cases. As wind force plays a major role as far as loading is considered in tall structures. For the details study of this project a case study is done considering a 100m high self supporting tower. In addition to the wind loading the loads of the communication antennas that will come on the tower are also considered. It describes the wind load calculations, analysis procedure and design of tower members. The tower is analyzed for both corner wind and face wind directions. Analysis if performed using SAP 80/90. The basic activity starts with modelling of the tower. Modelling of tower is an assembly structure with different configuration parts stands one above the other, each we call it as BAY. For this come typical bay types are formatted which could be used as data for generation of tower configuration. These typical configurations shall help in generation of easy model with different options in achieving the required parameters of optimum design results of minimum tonnage of the total structure with allowable deflections at maximum wind in both static and dynamic cases. Wind load and antenna load calculations are carried out by using 'C' program. Tower configuration, wind load calculations on tower, dimensions and properties of the tower (input to 'C') are explained by taking typical Bay-1. For analysis of tower, the required formatted input for Structural Analysis Program (SAP) is obtained by 'C') program output. Member forces are obtained by genol 1.f3f file (SAP output file). All tower members are designed as axially loaded compression members as per standard specifications. Design of members are carried out for maximum member forces obtained by both corner and face wind analysis. If capacity of member is less than member force higher sections are selected and analysis & design is carried out until member capacity is more than member force. Output (analysis & design data for all members is obtained using member forces file and "Design" C program file. This output is shown in Tables. Foundation forces and joint displacements are obtained by SAP output file (genol.sol) and the maximum deflection is checked as per specifications. In the tower structures, the leg members are governed when the wind acts in corner direction. Similarly the horizontal and diagonal members are governed when wind acts in face direction. The results tabulated shows the forces that are changing in static and dynamic loading.***

Index Terms**:** ***Bay, Communication tower, Dynamic loading, Sap***

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I. INTRODUCTION

The tall structures with relatively small cross section and with a large ratio between the height and maximum width are known as towers. The water towers, Radio and TV towers, Radar Communication towers, the towers of power transmission lines, cellular towers etc., are examples of structures belonging to the tower family. Now a days increase in usage of Cell Phones, increase the construction of communication towers. The communication towers used for Cell Phones transmission or for transmission tower or for FM transmission towers are of self supporting type. Environment effects such as wind load, ice load, temperature load and seismic largely influence Analysis & Design of these towers. The shape of the self supporting tower based on simple physics and is designed so that the maximum torque created by the wind is balanced by the torque due to self weight of the tower. Rapid advances in technological areas, such as power transmission, communication, broadcasting, have necessitated improvements in the design procedure of steel self supporting tower, in order to achieve maximum economy. Since the cost of the superstructure is dictated essentially by the tonnage of steel at various heights and since usually a typical standardized design is adopted for a large number of steel towers constructed, even a small percentage saving in the weight of steel consumed in each tower could result in substantial monetary savings. The design of such towers has undergone refinements in the past two decades. Approximations which reduced the three dimensional structure to planar structure, for manual analysis have given way to accurate three dimensional computer analysis based on the Finite Element Method. Laboratory tests (Sachs (1976)), which facilitate a more realistic computation of wind forces-taking into account diverse factor such as shape of the tower in plan, type of members(tubular or angle section) that the tower is made of and the exposed area of the tower have brought further refinements in load calculations. All towers are basically space structure. Towers with three or more legs are build to support transmission lines, tanks, radio and television, radar and microwave equipment, floodlight, bridges, etc. The tall towers required in the electronic industry are usually guyed. Most other towers are self supporting cantilevers. Transmission towers could probably be constructed mow economically as guyed if the greater width of required right of way were available and cheap. However, there is hazard that damage to a guy wire could cause collapse. Most towers especially a transmission lines, are of bolted construction.

Height limitations all towers above 150 ft in height must be approved by the federal aviation agency, and if the proposed structure is to support radio, radar, television, microwave or other electronics antenna or equipment a construction permits it is required from federal communications commission. When a tower is located near an airport or on an aeronautical flight path the towers height may be restricted by these agencies. Tall towers are required to have aeronautical obstruction lighting and painting, in accordance with sub part 17 C of the FCC rules and regulations. In determine the configuration of ground the towers or another conductor is a function of the line voltage and is specified by the national electric safety code of the national bureau of standards. The loads used in the design of transmission towers are discussed other towers the basic loads are those due to dead weight, live load, wind load, earth quake load and in, northern climates, ice or snow. Since the forces due to wind are critical in tall structures careful thought should be given to the wind pressure to be provided for. Minimum design loads in buildings and other structure of the American standards association recommends wind loading for all parts of the country and suggested at various heights above the ground.

In a four-legged tower the minimum wind loading on the column occur with a diagonal wind direction. Column loads are maximum on three legged tower with the wind normal to one side. Maximum stresses in the diagonals result when the wind is parallel to the other face. Ice and snow loads are related to climatic; in the northern part of the country it may be advisable to provide for an ice load corresponding to ½ in. of ice around all members. Including guys. Occasionally specifications required that towers be designed for full wind and ice is loads acting together. However, most codes do not require this, since ice is unlikely to build up under maximum wind. Earthquake forces are significant in the design of some towers, especially those support water tanks. In the design of guyed towers the stresses resulting from temperature change in the guys must e considered. Candelabra. It is often desirable to support more than one antenna on a single tower. The preferred arrangement is to mount one a top the other. When height restriction required multiple antennas at one level the structure is called candelabra. During erection, or as a result of the structure failure of an antenna is service, candelabra may be subjected to eccentric and or tensional load for single antenna tower. Stresses towers with constant batter. Towers whose legs are straight can be analyzed by assuming that each of the three or more tower faces is a plane truss. Loads can be replaced into components that lie in the planes of the tower faces at the joints. Each planar truss can be analyzed for the force components lying in its plane. the leg stresses are the sums of the stresses in the trusses of which the leg is a common chord. When the faces of a tower are identical in configuration, it is advantageous to compute the stresses in each member of a face resulting from applying separately at each joint in the face a unit horizontal load and a unit load parallel to the tower leg. Stresses from any combination of external loads can then be readily determined. The diagonal in horizontal numbers each face should be arranged so that they are subjected only to concentric axial load. Towers without constant better. When the legs are not straight the tower must be analyzed as three dimensional structure using the six equations of static equilibrium. When a system of horizontal bracing is added, as at the level where the leg better changes, the tower becomes statically in determinate. The stress in these horizontal diagonals may be assumed to be zero (unless forces due to torsion or present), which makes the structure determinate.

II. ANALYSIS PROCESS

The tower is analyzed using the FEM software structural analysis program SAP 80/90. The analysis is based on the stiffness matrix method of analysis of three dimensional trusses. The lattice tower is module of three dimensional structure. Members in the tower are modelled using 1 dimensional 2 nodded trust elements having three degrees of freedom per node. The module consist of main structural members in secondary bracings. The four tower legs transfer low to the isolated footings underneath them. The structure is assumed to have both translation and rotation restraints at theses four support points. The tower is analysed and design for both strength and deflection criteria at maximum design wind speed. The primary members are selected based on the forces and deformations, where as the secondary members for a slenderness ratio of 250.

The steps Involved in the Design of Self Supporting Tower:

- Selection of the configuration of the tower
- Approximate selection of member sized based on preliminary calculation end are experience.
- Computation and analysis of Dead load, live load, wind load, snow load, earth quake load, miscellaneous loads.

Design of tower members according to the forces obtained in the members, allowable deflection criteria and permissible stresses as per IS standards and customer specifications

Loads Acting on the Tower

The different loads that are acting the tower are wind load on tower members, antenna arrays, ladder, cables etc., dead load due to the attachment of antenna(band weight), ladder as well as the dead weight of the tower. The wind load ating on the supporting tower are obtained by estimating the total aerodynamic area of the tower, antenna.an amount0of shielding is considered while applying the wind load due to antenna arrays on the tower. For analysis purpose, the proposed 100M height tower0considered and it is at unbound snow region. Hence, snow load is not considered.

III. SELECTION OF TOWER CONFIGURATION

The configuration of the tower (base width, top width and bracing system) should be selected based on user's specifications of antenna, platform etc., aesthetic considerations and previous experience in the design of towers, and the engineering judgment of the designer. A nuber of different bracing systems such as 1. Single web system, 2. Warren system (X bracing), 3. Pratt system, 4. Prtal system (K bracing), and 5. Diamond system may be adopted for the members of the tower. Research conducted on these bracing systems has shown that the portal system and the warren system will result in optimum weight. In very high towers, the main bracing members will be very long and hence have to be stiffened by secondary bracing members. Hence, it is an usual practice to provide portal system (with secondary bracings) up to certain height of the tower and warren (x-bracing) system for the rest of the height. The selected tower is square in plan for analysis purpose. The complete tower election with bracing system is as shown in Figure.

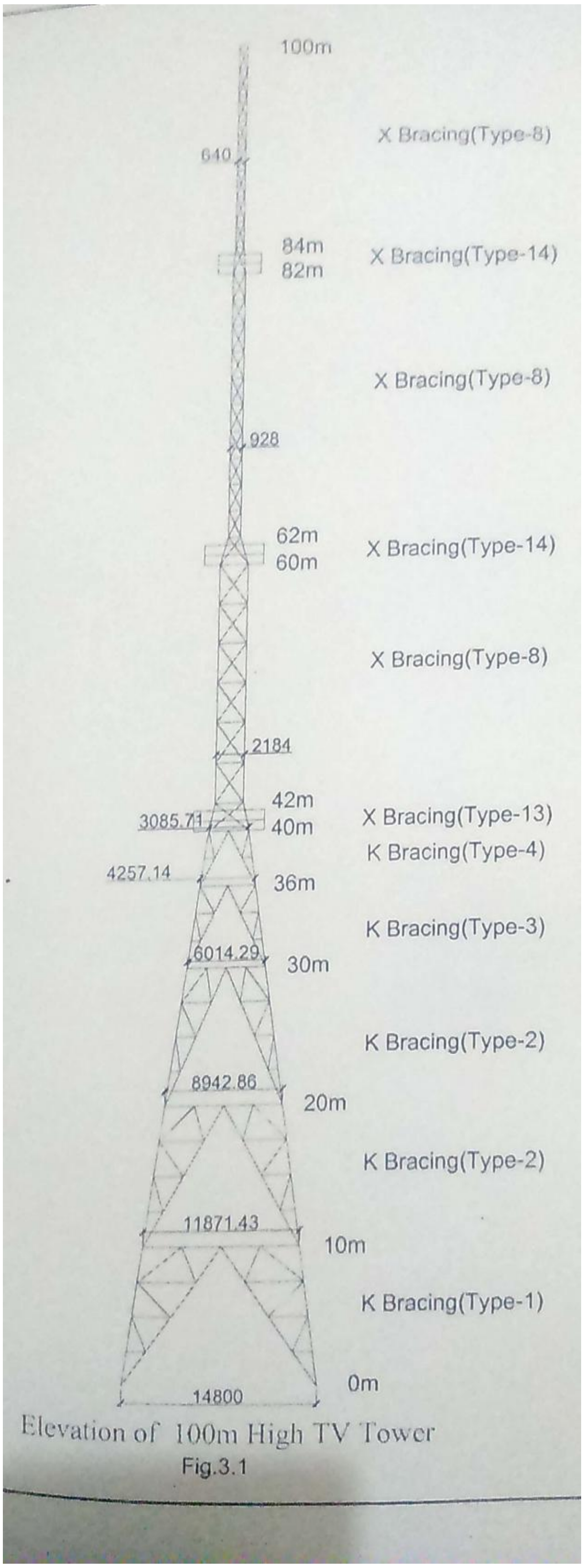

Fig.3.1

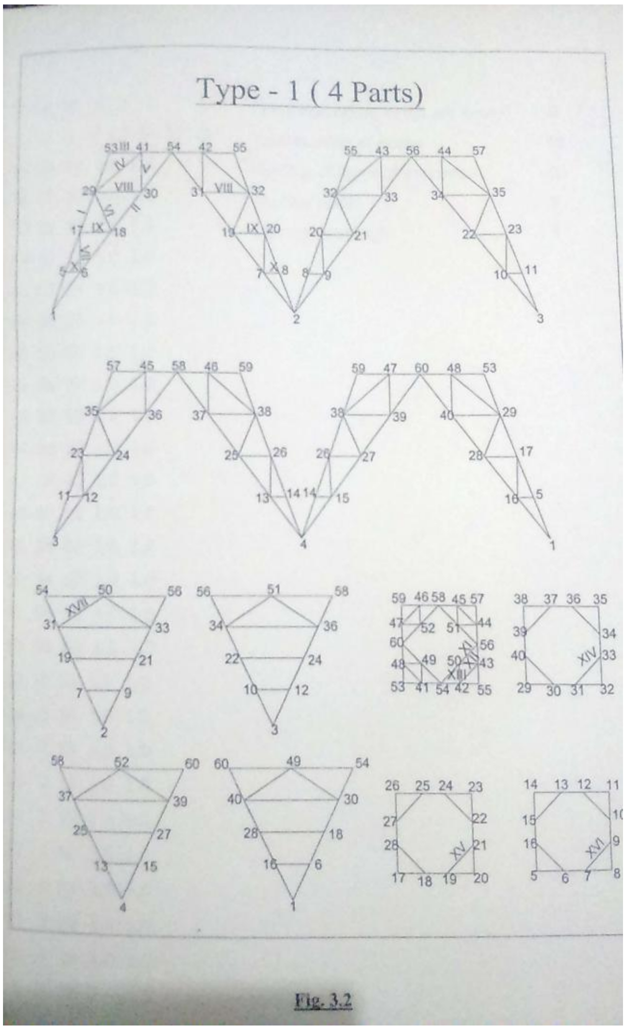

Fig. 3.2

This Indian Standard (Part 3) (Second Revision) was adopted by the Bureau of Indian Standards on 13 November 1987, after the draft finalized by the Structural Safety Sectional Committee had been approved by the Civil Engineering Division Council. A building has to perform many functions satisfactorily. Amongst these functions are the utility of the building for the intended use and occupancy, structural safety, fire safety and compliance with hygienic, sanitation, ventilation and daylight standards. The design of the building is dependent upon the minimum requirements prescribed for each of the above functions. The minimum requirements pertaining to the structural safety of buildings are being covered in loading codes by way of laying down minimum design loads which have to be assumed for dead loads, imposed loads, wind loads and other external loads, the structure would be required to bear. Strict conformity to loading standards, it is. hoped, will not only ensure the structural safety of the buildings and structures which are being designed and constructed in the country and thereby reduce the hazards to life and property caused by unsafe structures, but also eliminate the wastage caused by assuming unnecessarily heavy loadings without proper assessment. This standard was first published in 1957 for the guidance of civil engineers, designers and architects associated with the planning and design of buildings. It included the provisions for the basic design loads (dead loads, live loads, wind loads and seismic loads) to be assumed in the design of the buildings. In its first revision in 1964, the wind pressure provisions were modified on the basis of studies of wind phenomenon and its effect on structures, undertaken by the special committee in consultation with the Indian Meteorological Department. In addition to this, new clauses on wind loads for butterfly type structures were included; wind pressure coefficients for sheeted roofs, both curved and sloping were modified; seismic load provisions were deleted. (Separate code having been prepared) and metric system of weights and measurements was adopted. It is believed that ultimately wind load estimation will be made by taking into account the random variation of wind speed with time but available theoretical methods have not matured sufficiently at present for use in the code. For this season, static wind method of load estimation which implies a steady wind speed, which has proved to be satisfactory for normal, short and heavy structures, is given in 5 and 6. However, a beginning has been made to take account of the random nature of the wind speed by requiring that the along-wind or drag load on structures which are prone to wind induced oscillations, be also determined by the gust factor ethod (see 8) and the more severe of the two estimates be taken for design. A large majority of structures met with in practice do not however, suffer wind induced oscillations and generally do not require to be examined for the dynamic effects of wind, including use of gust factor method, Nevertheless, there are various types of structures or their components such as some tall buildings, chimneys, latticed towers, cooling towers, transmission towers, guyed masts, communication towers, long span bridges, partially or completely solid faced antenna dish, etc, which require investigation of wind induced oscillations. The use of 7 shall be made for i.dentifying and analysing such structures. Tower is analyzed for front and diagonal wind directions. The wind loading on the tower is calculated as per IS 875:1987. Basic wind speed 39m/s has been taken for the tower based on geographical location of site given in wind zone map of India. Design wind speed is calculated considering effects of risk level, terrain roughness, height and size of the Terrain category 2 and class of structure class-C are selected calculate terrain category factor (K2). The tower is proposed on plain ground and hence a value of 1.0 is consider red as topography factor (K3).

Typical Wind Load Calculation for Bay-(0-10m):

Wind force normal to the surface **F= Cf*A*Pz**

Where, Cf = Force coefficient based on solidity Ratio Ø

A= Aerodynamic Area of the members

Pz= Design Wind Pressure = 0.6 V_z^2

(As per clause 5.4, IS 875(part3)-1987)

Vz= Design wind speed = Vb*K1*K2*K3

(As per clause 5.3, IS 875(part3)-1987)

Vb= Basic Wind speed

K1= Risk Coefficient

K2= Terrain Height and Structure Size Factor

K3= Topography Factor

Basic Wind Speed Vb=39m/sec

(As per Basic wind Speed map of india, IS 875(part3)-1987)

Risk Coefficient(K1 factor)=1.06

(As per the table 1, Clause 5.3.1, IS 875 (part3)-1987)

Terrain Height and Steucture Size Factor (K2 factor)=0.93

(As per the table 1, Clause 5.3.2.2, Terrain Category 2 –Class C, IS 875 (part3)-1987)

Topography Factor (K3 factor) =1.0

V. CONCLUSION

From the analysis of the tower the following conclusions are obtained. The wind forces on the tower increases as height increases. It is observed from the analysis results that the forces in the leg members are more when wind force acts in tower corner direction. Similarly the forces in the horizontal and diagonal members are more when wind forces acts in tower face direction. The natural frequency of the tower values is less than 1, and the member forces of the tower in dynamic analysis are more than the member forces in static analysis due to guest factor. The maximum deflection occurs at the top of the tower. This deflection also maximum in dynamic analysis. The deflection is maximum when wind force acts in the tower face direction. The foundation forces are also governs in dynamic analysis. The maximum foundation forces of upward trust, Download force, shear are maximum when force acts in the tower corner wind direction. The forces from the analysis are taken in designation the tower members. The conclusions from the design of the tower. the tower is safe Against static and dynamic analysis considering wind loads, self weight of tower and loads of antenna arrays. All tower members are safe and meeting the requirements as per IS:800. The tower is safe against deflection at maximum design wind speed. The maximum deflection of 975mm is obtained at 100m level. It is less than the allowable deflection of 1 in 100. To design the foundation, maximum forces such as uplift, down load, uplift shear & down load shear are obtained by corner wind analysis. These forces are maximum at four leg points(at base level). All redundant members are designed to meet the required (As per the table 1, Clause 5.3.3.1, IS 875 (part3)-1987)

Design Wind Speed Vz=Vb*K1*K2*K3

= 39*1.06*0.93*1.0

= 38.4462 m/sec

Design of Wind Pressure Pz= 0.6* V_z^2

= 0.6*38.4462^2

= **886.87 N/m2**

Typical Calculation Of Solidity Ration:

Solidity ratio is equal to the effective area (projected area of all the individual elements) of a frame normal to the wind direction.

Bottom width of the Bay	=	14.8m
Top width of the Bay	=	11.871m
Height of the Bay	=	10.2121m
Total area of the bay	=	(14.50+11.871)/2*10.2121
	=	**136.18m2**

slenderness ratio of 250. Member forces and capacity of main members are shown.

Scope for Future Study:

The tower are tall steel structure which serve for the communication network systems. Hence considering the potentiality and its demand a need has come to optimize the tower structure for minimum tonnage of the structure. It also ensured that the safety of the members and the structure should deflect well with in its specified tolerances.

There is much scope to dissertise on this by providing tubular section in place of angular members on the tower. Similarly lot of detailing is involved in generation of components drawings for shop manufacturing. Hence atomization can be possible for generation of detail shop drawings also with raw materials list, fasteners list etc., to give the required requirements.

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AUTHORS PROFILE

I **Mr. S. Kailash Kumar** completed my M.tech in Structural engineering from MREC college Affiliated to JNTU Hyderabad, secured 9.6 CGPA, B.Tech in Civil Engineering secured 79.26% from KSIT college Affiliated to JNTU Hyderabad. I have completed my Intermidiate from Shambhavi junior college secured 86.6% and schooling from shishumandir high school Bhainsa, Telangana secured 85.3%. Technical wise I have knowledge in Auto CAD, Staad.Pro, Revit Architecture and Sketchup.

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1.I have published an International journal in IJRSAE title EXPERIMENTAL INVESTIGATION ON GEO POLYMER CONCRETE.
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4.Participated in National conference on INNOVATIVE RESEARCH IN CIVIL ENGINEERING- NCIRCE 2K17 in MREC college.
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I **Mr. Gundrala Prashanth** completed my M.tech in Highway engineering from TKRCET college Affiliated to JNTU Hyderabad, secured 68.75%, B.Tech in Civil Engineering secured 70% from SKEC college Affiliated to JNTU Hyderabad. I have completed my Intermidiate from Sri Chaitanya junior college secured 75% and schooling from Nirmala high school Dornkal, Telangana secured 78%. Technical wise I have knowledge in Auto CAD, Staad.Pro, Revit Architecture and Sketchup.

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