ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

# Case Study on Structural Behavior of Lattice Tower on a Building

**Kolli Jahnavi**
**Department of Civil Engineering**
**Universal College of Engineering and Technology,**
**Andhra Pradesh 522005, India.**

**Pratti Anil Kumar**
**Department of Civil Engineering**
**Universal College of Engineering and Technology,**
**Andhra Pradesh 522005, India.**

## ABSTRACT

***The increasing trend of mobile communications has seen exponential growth in the last three years. Increased competitions among mobile operators also have contributed to the installation of many towers to enhance both coverage area and network reliability. The tower locations as specified in terms of latitudes and longitudes with the height of mounted antenna dictated by functional requirements of the network. The availability of land which satisfies ideal installation conditions in urban areas is extremely limited giving no alternative but to adopt roof top towers (with marginal adjustment in position but not in height).***

***In the present study ,the response of 4 – legged angled section and 3 legged tubular section roof top telecommunication Lattice tower has been studied on existing building(G+5) under the effect of wind analysis for zone II as per IS 875 (part 3)2015 - Design Loads (other than Earthquake) for buildings and structures – code of practice . The analysis has been performed on towers located on the roof of host structure by varying positions and without changing height with specified wind speed using STAAD Pro. Software. The wind force is considered as governing factor of the structure. The axial forces in roof top Lattice tower stresses, inter-story drift and torsion effect on host structure due to rooftop tower are considered as the main parameter for the study.***

***Key Words:* Rooftop Lattice tower, STAAD Pro, wind analysis.**

## Introduction

In the contemporary era, the telecommunication industry plays a major role on creating sustainable society, and thus much more attention is now being paid to telecommunication towers than it was in the past. The functional requirement of telecommunication towers is enhancing both coverage and network reliability, and are governing factors on defining height of structure and proposed antenna characteristics. The frequencies used in digital mobile phone networks are 900MHz, 1800 MHz and 2100 MHz frequencies are currently being used in fourth generation technology, in which structure height varies between 10 to 80m height. Height of antenna from average ground level can vary between 35-45m for GSM / CDMA Technology [1-4] and more elevated height would be require for Microwave link (Higher dishes) ranging 50-80m from normal ground level. In this scenario, self-supporting Lattice towers are being effective structural system by considering simple, light weight, easy fabrication and installation and these lattice towers either ground based, or roof mounted to achieve desirable height of structure. The self - supporting towers are normally square or triangular in plan and made up of steel angle or circular hollow section. Wind is major environmental load on these cantilevers slender structures and are analysed as space truss structure.

Lattice Steel towers have provided an economic solution for the Telecommunication Industry over many years. These towers are either in square or triangular cross section in plan and are constructed through bolted connection or welding. The design of such structures evolved rapidly with the advent of transmission lines, whose towers were designed for maximum efficiency –

**Cite this article as:** Kolli Jahnavi & Pratti Anil Kumar, "Case Study on Structural Behavior of Lattice Tower on a Building", International Journal & Magazine of Engineering, Technology, Management and Research, Volume 6 Issue 7, 2019, Page 94-100.

that is the lowest weight of steel. Typically lattice steel towers vary in face width from top to bottom and depending on the form of structure, different bracing pattern are adopted appropriate to the loading to be carried. The main advantage of self-supporting lattice structures lies in their good torsional rigidity compared to guyed mast [3]. The design problems are relatively straight forward and are amenable to well established principles, although many secondary members are used, to reduce the effective lengths of primary load carrying members in wide faced towers. Wind is predominant load for analysis of these slender light weight structures, hence thorough understanding of basic concepts of wind and their influencing parameters are essential while dealing of these lattice structures.

## Wind and Influencing Parameter

Wind means the motion of air in the atmosphere with respect to surface of the earth is fundamentally caused by variable solar heating of earth's atmosphere. The earth surface exerts on the moving air a horizontal drag force, whose effect is to retard the flow. This effect is diffused by turbulent mixing throughout a region referred as Atmospheric boundary layer. The depth of boundary layer depending up on the wind intensity, roughness of terrain, and angle of latitude. Within the boundary layer, the wind speed increases with elevation its magnitude at the top of boundary layer is often referred to as the gradient speed. Outside the boundary layer, that is in free atmosphere the wind flows approximately with the gradient speed along the isobars. Information on atmospheric turbulence is useful in structural engineering application for three reasons. First, rigid structures and members are subjected to time-dependent loads with fluctuations due in part to atmospheric turbulence. Second, flexible structures may exhibit resonant amplifications effects induced by velocity fluctuations [5-7].

## Wind Resistance

Wind Resistance is defined as the resistance to the flow of wind offered by the assembled components of a tower and by any elements which it supports shall be derived from the force coefficient given in relevant standards. The term wind resistance to encompass the combination of area, shielding effects and drag characteristics (Force coefficient) [2].

## Structural Response to Wind

Wind force is essentially dynamic in nature even though it is treated as steady force for simplicity in the analysis and design of wind sensitive structures. Due to turbulent nature of wind velocities, the wind loads acting on structure are also highly fluctuating. The back-ground response, made up largely low-frequency contribution below the lowest natural frequency of vibration is the largest contributor for along wind loading. The Resonant contribution becomes more significant, will eventually dominate as structure becomes taller in relation to their width and their natural frequencies becomes lower. As a rule of thumb, the lowest natural frequency should be below 1 Hz for the resonant response to be significant. When structure experiences resonant dynamic response, counteracting structural forces [4] come in to play to balance wind forces are,

- Inertia forces proportional to mass of structure
- Damping or energy absorbing forces
- Elastic or stiffness force proportional to deflection

## Lattice Steel Towers

Lattice steel towers are further classified in to – square and triangular towers based on their cross section in plan. Square towers consist of four legs of steel angle profiles separated with face width based on loading requirement. Square towers are more widely used in telecom industry by considering easiness of material availability, fabrication and installation through bolting of angle at site. Equilateral triangular towers consist of three legs separated with face width is used in place of square towers due to their lesser wind resistance compared to square towers [6-8].

Equilateral triangular towers having sub configuration based on their usage of profiles for legs and bracings / secondary members. Optimum solution proved to be a triangular tower with legs in circular tubes and cross diagonal bracings are either circular / square tubes. Tubes are very effective profiles when the design forces are compressive, as they have larger stiffness for small steel area, which means that the lattice structures may be quite 'open', minimizing the number of structural elements. On the other hand, the material price for steel tubes is, in general, relatively high compared with other profiles such as angles and solid round bars. When using circular tubes as legs, welding cannot be totally avoided and involves welding of gusset plates and of the flanges for the joints of the legs, but when welding is necessary it is normally good idea to minimize the number of elements that need it. Major limitation of using tubes is the difficulty of detecting the internal corrosion that could occur if the galvanizing is faulty. Therefore, as the wind forces on main legs contributing overall stability of tower, it is good idea to use legs as circular profiles and bracing members as angular profiles to be connected on gusset plate which can be welded to circular profile. This configuration can be referred as Triangular – Hybrid Configuration [5].

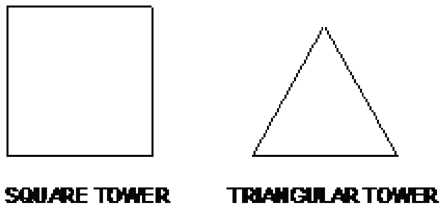


Fig. 1.1: Typical Tower Plan

## Retrofitting Techniques

Out of the various structure elements in building, columns are more vulnerable to damages and could prove to be disasters if unattended. Column jacketing is the most popular and commonly adopted technique for strengthening the existing columns. Enlarging the cross section of an existing column will strengthen the column by increasing its load carrying capacity. A column can be enlarged in various configurations. However, the drying shrinkage effects in the concrete used to enlarge the column must be considered. Drying shrinkage, if restrained will introduce the tensile stresses in the new portion of the column [6].

## Concrete Jacketing

Concrete jacketing involves addition of a layer of concrete, longitudinal bars and closely spaced ties. The jacket increases both the flexural strength and shear strength of the column and Increase ductility as well. If the thickness of the jacket is small there is no appreciable increase in stiffness. Circular jackets of ferro-cement have been found to be effective in enhancing the ductility. The disadvantage of concrete jacketing is the increase in the size of the column. The placement of ties at the beam-column joints is difficult, if not impossible [4]. Drilling holes in the existing beams damages the concrete, especially if the concrete is of poor quality. Although there are disadvantages, the use of concrete jacket is relatively cheap. It is important to note that with the increase in flexural capacity, the shear demand (based on flexural capacity) also increases. The additional ties are provided to meet the shear demand.

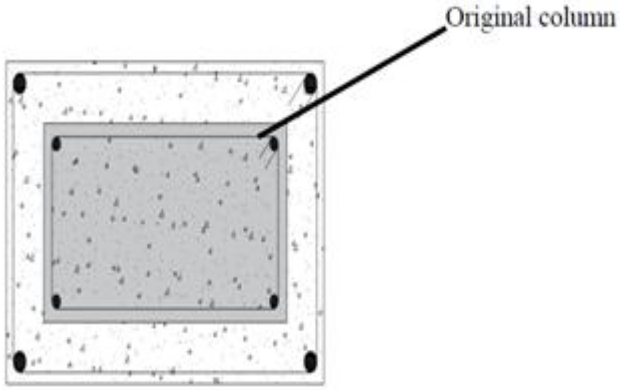


Figure 1. Standard cross-section of reinforced concrete jacket

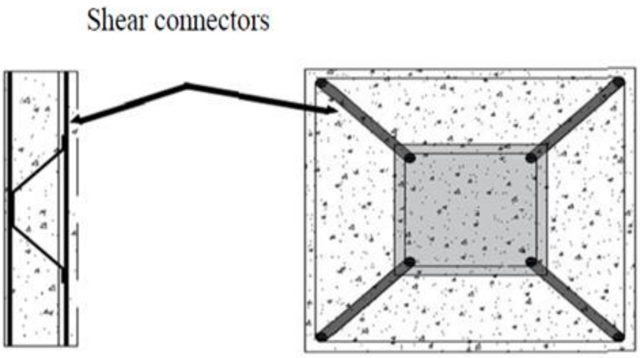


Figure 2. Profile of shear connectors between original column and jacket reinforcement

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

## Structural Behavior of Bracing system

### Typical Bracing System

There are many type of bracing patterns used in the design of steel lattice towers, each of which has its own advantage and disadvantages.

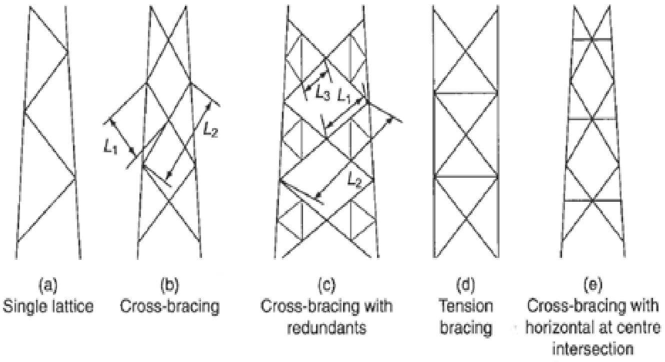


Figure 3. Typical Bracing Patterns

a) Single Lattice: Commonly used where member loads are light and length relatively short. This system is used for narrow based towers.

b) Cross-Bracing: This is most frequently used type of bracing. The main advantage is that, provided the load is equally or nearly split in to tension and compression, the centre of cross may be considered as point of restraint both transverse to and in the plane of the bracing.The behavior of cross bracing pattern has been investigated by Kemp and Behncke, concluded that the behavior is dependent on the end eccentricity and on the number of bolts in the end connection between the cross-bracing member and the main legs. It was shown that the centre joint does act as an effective restraint to buckling of the members for slenderness ratio ranges between 100 and 160.

c) Cross-Bracing with redundant: In this, the redundant are inserted to stabilize the legs but they also reduce the buckling length of bracing member.

d) Tension Bracing: These are usually used in masts where the legs are parallel – the diagonal tension members are designed to carry the total shear in tension, and the horizontal member is designed to carry the total shear in compression. These are very sensitive to methods of erection and to modifications or relative movements.

e) Cross-Bracing with Horizontal at Centre Intersection: The horizontal member must be sufficiently stiff in transverse direction to provide restraints for the load cases where the compression in one bracing member exceeds the tension in the other or in the situation when both members are in compression.

In like above, different bracing patterns exists in K-Type Bracing as well which are listed below.

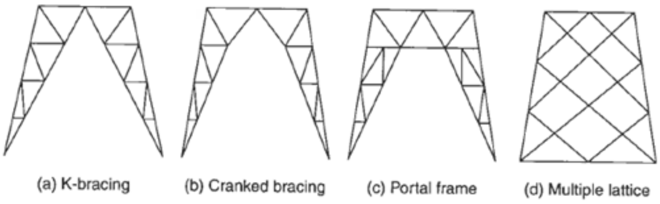


Figure 4. Typical K-Bracing Patterns

a) K-Bracings: This is popular type of bracing for the lower panels of towers or towers where ordinary cross-bracings would be too long. It has the merit of ensuring that horizontal shear load on the tower panel is equally distributed in to the compression and tension bracing members.

b) Cranked K-Bracing: when the width of tower becomes larger it is sometimes more economic to introduce a crank or bend in to the main diagonals. This has effect of reducing the length and size of redundant but produces high stresses in the members meeting at the bend and necessitates transverse support at the joint.

c) Portal Frame: One way of reliving the high stresses at the bend in the case of ‘Cranked K-Bracing’ is to introduce a horizontal at this point and turn the panel in to portal frame. This pattern careful consideration when foundation settlement or movement occurs.

In any bracing type, if the included angle between a bracing member and the member it support is small, the bracing member should not be considered as providing full support; as the included angle approaches 150, the supported member shall be investigated for stability.

## Wind Resistance – Discrete Accessories

Discrete ancillary is of any nonstructural components that is concentrated within a few panels, such as dish reflectors, aerials, lighting, platforms, handrails, insulators and other items. Typically, two different antenna types observed in telecom towers for wind loading consideration– Flat type antenna (GSM / CDMA) and Parabolic dish antenna. Wind loads can be calculated based technical data sheets from antenna manufacturer or from force coefficient (dependent on type of antenna and their aspect ratio - length / width) from relevant standards. Different Type of MW Antenna is shown in below figure

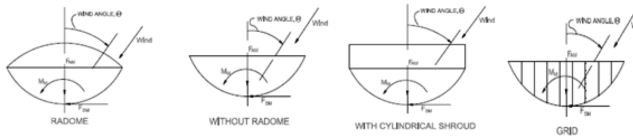


Figure 7. Different Type of MW Antenna

## Panel Wise Wind Load

Wind forces on tower body are distributed to the all sectional points at an elevation equally with a fact that force coefficient has accounted for both wind ward and leeward tower faces including shielding effects. And wind forces on linear accessories – climbing ladder, cables) are distributed equally at all three nodes at each sectional point due to their symmetrical location with respect to tower. Wind forces on discrete accessories (such as antenna) are distributed to the respective member connecting joints as concentrated vector loads. In triangular towers, the maximum leg loads occur in the single leg on the axis of the tower in the wind direction with wind normal to one face. For bracing members, the maximum force occurs for wind parallel to face in the plane of bracings in wind direction. Therefore, three wind directions are considered with respect to tower for towers nearly symmetrical in geometry and loading.

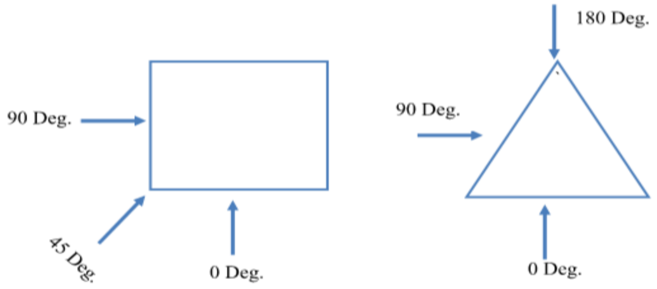


Figure 1. Wind Directions for Tower Analysis

## Analysis Results

Lattice steel tower are idealized as space truss and modelled in STAAD Pro software (Commercial software, which are widely used in structural analysis and design of civil engineering structures), and loads are applied as nodal loads as per their respective location on the structure [3-5].

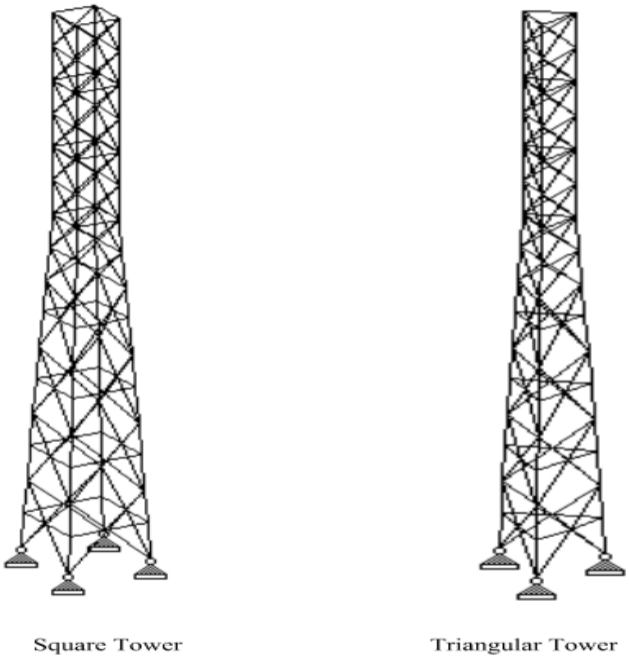


Figure 10. Lattice Tower Analysis Models

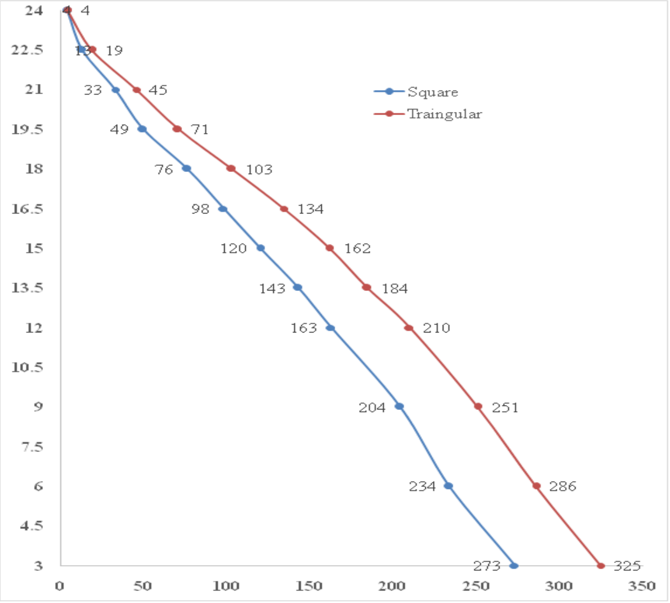


Figure 11. Maximum Un factored Leg forces (kN)

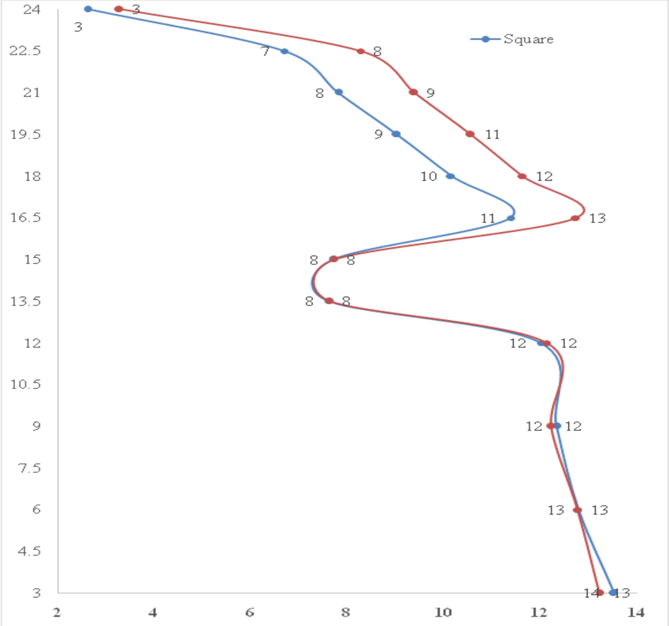


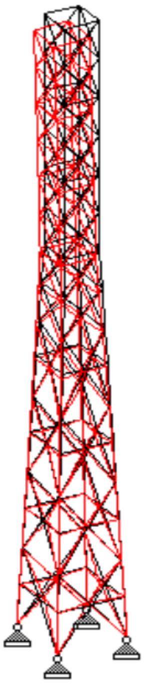
Figure 12. Maximum Un factored Bracing forces (kN)

### Maximum Displacements

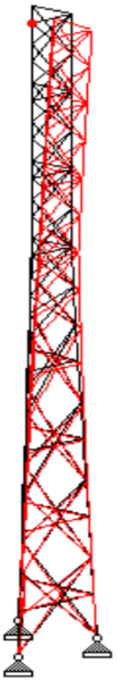
Maximum Displacement (at design wind speed, with load factor 1.0) at top of Tower are,

Square Tower : 118.11mm

Triangular tower : 114.59 mm



Square Tower, 45 Deg. Wind



Triangular Tower, 0 Deg. Wind

### Summary

In this current project, two tower configuration – square tower made up of angular sections, triangular tower where legs are made up of circular hollow section and bracings with angular profiles were studied for obtain economical structural configuration in view of lesser wind resistance and base reaction for a given functional requirement. Further the study is extended to check feasible location in existing building through comparison of tower placed in different location i.e., corner and center of building and traditional strengthening technique of column jacketing was applied for best feasible location to enhance strength of existing column for tower reactions.

### Conclusions

Following conclusions are drawn from the detailed analysis and study.

1. Triangular Tower (legs with circular hollow sections, bracings with angle sections) located in center of building observed as best feasible location compared to all other options.
2. Triangular Tower attracts lesser wind resistance lead to lesser base moment and lesser base reaction to square tower
3. Symmetrical distribution of wind reaction at base of tower is observed in triangular tower for any wind direction compared to square tower.
4. Columns located in centre of building may not effect much due to wind load on building and as well biaxial bending is most unlikely to occur due to continuous spans around the column
5. Columns located in centre of building original designed for higher load due to continuous spans, thus less increase of forces observed due to tower loadings.
6. Ground floor columns found inadequate for triangular tower reactions, hence strength enhancement is performed using column jacketing.
7. In column Jacketing, minimum requirement are governed the strengthening and is easy to implement for centre column rather than corner of column due to space constraints.

## REFERENCES

[1] Siddesha.H (2010): “Wind Analysis of Microwave Antenna Towers”,International Journal of Applied Engineering Research, Dindigul, Volume 1, No 3,ISSN:0976-4259,574-584,

[2] Nitin Bhosale, Prabhat Kumar, PandeyA.D (2012): “Influence of host structure characteristics on response of rooftop telecommunication towers”, International Journal of Civil and Structural Engineering Volume 2, No 3, ISSN 0976-4399, 737-748,

[3] Ghyslaine McClure, Laura GEORGI and Rola ASSI (2004): “Seismic Considerations for Telecommunication Towers Mounted on Building Rooftops” ,13th World Conference on Earthquake Engineering Vancouver, B.C., Canada,19-88 ,

[4] Bhatt, R., Pandey, A. D. & Prakash, V. (2013) : “Influence of modeling in the response of steel lattice mobile tower under wind loading”, International Journal of Scientific Engineering and Technology,

[5] C Preeti, (2015): Comparative study of four legged self-supported angular telecommunication tower on ground and mounted on roof top, Volume: 04 Issue: 10 | Oct-2015, eISSN: 2319-1163 | pISSN: 2321-7308.

[6] Amiri, G. & Boostan, A. (2002):“Dynamic Response of Antenna-Supporting Structures”,4th Structural Specialty Conference of the Canadian Society for Civil Engineering. p.1-9,

[7] Rajasekharan, J. & Vijaya, S. (2014): “Analysis of Telecommunication Tower Subjected to Seismic & Wind loading”,International Journal of Advancement in Engineering Technology, Management and applied science,

[8] Gnana sekaran Kaliyaperumal (2009) : “Seismic retrofit of columns in buildings for flexure using concrete jacket “,ISET Journal of Earthquake Technology, Paper No. 505, Vol. 46, No. 2, June 2009, pp. 77–107,