

A Review on Impact of Earthquake and Wind Force on The Structural Behavior of Monopole and Self-Supporting Towers

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Abstract—With the rapid and exponential increase in the usage of mobiles, a lot of attention is being paid on the telecommunication industry and telecommunication towers in the recent past. Each and every individual is carrying a mobile with him/her nowadays and the demand for telecommunication services has increased. Telecommunication Towers are the only means for coverage area and network reliability. Civil Engineers are involved in the analysis and design of the towers that support the panel antennas, telecommunication equipment, platforms and their foundations. All the equipment's like mounts, antennas etc. are mounted on the tower which requires Civil engineering expertise. Tower structural calculations include Applied Loads like wind load, dead load, seismic load and design strength of structural steel member on superstructure including connections and foundation.

Index Terms—Civil engineering, Steel. Dynamic, Wind Load, FEM, Telecommunication Towers.

I. INTRODUCTION

In the contemporary era, the telecommunication industry plays a great role in human societies and thus much more attention is now being paid to telecommunication towers than it was in the past. At times of occurrence of natural disasters, telecommunication towers have the crucial task of instant transmission of information from the affected areas to the rescue centres. In addition, performance of infrastructure such as dams, electric, gas, and fuel transmission stations, depends extensively on the information being transmitted via these telecommunication towers. Military and defence industries in addition to television, radio, and telecommunication industries are other areas of

application for such towers and thus create the necessity for further research on telecommunication towers. Telecommunication towers are tall structure usually designed for supporting parabolic antennas which are normally used for microwave transmission for communication, also used for sending radio, television signals to remote places and they are installed at a specific height. These towers are self-supporting structures and categorized as three-legged and four-legged space trussed structures. The self-supporting towers are normally square or triangular in plan and are supported on ground or on buildings.

A. Self-Supporting towers

A self-supporting tower (freestanding tower) is constructed without guy wires. Self-supporting towers have a larger footprint than monopoles, but still requires a much smaller area than guyed masts. Due to its relatively small footprint, this kind of tower is commonly seen in cities or other places where it is short of free space. The wider the base of the tower is, the larger antenna load is acceptable. Self-supporting towers are square, rectangular or triangular in plan. Though the weight of these towers is more they require less base area and are suitable in many situations. Most of the TV, MW, Power transmission, and flood light towers are self-supporting towers. Self-supporting towers does not have limitation of height for construction and hence use widely. Based on the location of tower where it is installed, Self-supporting towers can further be classified as ground base towers and rooftop tower.

B. Guyed Towers

Guyed towers are hinged to the base, and are supported by guy wires attached to it at various levels, to transmit

the wind forces to the ground. A guyed mast is a tall thin vertical structure

its own weight, but usually does not have the shear strength to stand unsupported, and requires guy lines, diagonal tensioned cables attached to the ground, usually spaced at equal angles about its base, to resist lateral forces such as wind loads and keep it upright. Guyed towers provide height at much lower material cost than self-supporting towers due to efficient use of high strength steel in guy. Guyed towers are normally guyed in three directions over an anchor radius of typically 2/3rd of the tower height and have a triangular lattice section for central mat. Tubular masts are also used, especially where icing is very heavy and lattice sections would ice up fully. These towers are much lighter than self-supporting type but require a large free space to anchor guy wires. There is other restriction to mount dish antennae on these towers and requires large anchor blocks to hold the ropes.

C. Monopole

Monopole towers are self-supporting pole developed for the telecommunication business as an alternative to the lattice tower. Its characteristics are a slim design without visible assembling between the sections and a high load capacity with a small deflection in the top. The monopole towers are designed for up to four operators without making the deflection exceed more than 1 degree. The monopole towers can be delivered with extra equipment such as a combined ladder and safety device system as well as an anti-climb device in the bottom. Monopole is generally placed on roof of the building or on ground when the size and no of antenna required is less or height of tower required is up to 20 meters.

II. STATE OF DEVELOPMENT

Prachi A. Uchade et. al. (2022)

In telecommunication industry, lattice towers are the most commonly used structure. But in this new era, Monopoles are also being used in place of lattice towers. This paper presents a comparative study between Monopole and Lattice type Towers with different heights, keeping other parameters constant. The tower heights taken into consideration for this investigation are 30 m, 40 m and 50 m. Dead loads and Wind loads are considered for analysis of the tower using STAAD Pro software which is made for

analyzing different structures. Basic wind speed taken is 44 m/s. Designing and analysis of towers is done on STAAD Pro keeping its height and loading constant and later comparison is carried out from the results obtained after analysis on STAAD. Monopole is an advance structure which requires less material and less space for installation than compared to conventional lattice towers. In this era, as population is increasing, requirement of land and its cost is continuously increasing and hence modification in traditional lattice towers is essential. During this paper work, past research supporting analysis of towers and monopole has been studied.

Syed. Ehtesham Ali et. al. (2022)

The purpose of the proposed research is to study the structural behavior of monopole towers with and without camouflaged with 35m height of tower with basic wind speed of 44.44m/s, as per latest current code ANSI/TIA 222-H. Most studies and research have shown only structural behavior of monopole towers with other type of lattice towers. Proposed research is very important because the structural engineer faces the challenging job of designing and constructing telecommunication towers to support all loads in open weather with high degree of reliability. Free standing lattice towers are generally used in all over the world. As per the recent surveys, mobile towers in the world are likely to grow very fast due to the introduction of 5G technology which requires more antennas on the towers, with existing monopole towers already occupied with lot of antennas with no structural capacity to withstand extra load on towers. New camouflaged designs in monopole are going to study in this research to improve monopole structural capacity and structural behavior to withstand new loads. Environmental and economic pressures have initiated to seek improved design approaches to make communication towers more environmentally acceptable and cost effective. Since monopole structures have smaller dimension and require lesser space for installation, they can be used as a suitable alternate for lattice towers. Some researchers observed in their study that monopole towers have higher lateral displacements and lesser monopole structural capacity than self-supporting towers. In this proposed research a new camouflaged technical design is developed to study the structural behavior of monopole towers. This research shall be helpful for determining lateral

displacement of monopole, monopole capacity and effect of wind speeds for 35m height of monopole towers with and without camouflaged under the influence of wind load.

Shwetha Shetty M R et. al. (2019)

The four-legged self-supporting towers are widely used worldwide for the telecommunication purposes. The communication industries have seen a tremendous increase in last few years which have resulted in installation of large number of towers to increase the coverage area and network consistency. These are lifeline structures; they play a significant role in wireless communication network. Hence failure of such structures in a disaster like wind and earthquake is a major concern. Therefore, utmost importance should be given in considering all possible extreme conditions for designing these towers. The design of these steel telecommunication towers is done by the STAAD.PRO, for this “automatic selection of members based on reanalysis procedure with fixed group select optimized section” method is adopted.

Ravichandran P et. al. (2019)

Communication towers have been traditionally designed for wind load. The earthquake load has not been observed in the analysis of the communication tower. Recent earthquakes, there have been indications of collapse to the communication tower. Due to the complex nature of the problem, there is a lack of research work in the area of analysis of the communication tower. The purpose of this research is to test the communication tower's response to earthquake ground movement to determine the current design software methodology. The effect of earthquake ground motion spatial variation on multi-support structures dynamic response may be necessary. The aim of this project is to use the traveling wave assumption to investigate the seismic response of high antenna-supporting guyed towers. The horizontal component of the Bhuj earthquake is considered as excitation. Elements of response analyzed are cable tension, base shear, mast axial force and lateral displacement of the tower tip. Parametric analyses show that the structural response tends to increase as the amplitude of the wave decreases and can become much larger than the reaction from synchronous excitation.

Veena G et. al. (2017)

The telecommunication masts are considered today as one of the basic infrastructures in the human societies. Due to their vital role, the preservation of these structures during natural disasters, such as a severe earthquake, is of utmost priority and hence their seismic performance should be properly evaluated. The researchers in their studies have considered the effects of wind and earthquake-induced loads mostly on the trussed steel masts of triangular cross sections. The telecommunication towers exposed to special loadings such as longitudinal loads, construction, and maintenance loads, line galloping, and structure vibration, for which it need to be designed. Longitudinal loadings may be the result of weather – related events, failure of an adjacent structure and must be resisted to prevent cascading failures of the support structures in the line. For this reason, longitudinal loadings are sometimes referred to as “Anti cascading” failure containment” or “Security” loads.

M. Pavan Kumar et. al. (2017)

Monopole and Self-Supporting Towers are the most common types of Telecommunication Towers adopted in construction industry. This paper presents a comparison between Monopole and Self-Support type Towers with different heights of 30m, 40m and 50m for basic wind speeds of 33m/sec, 47m/sec and 55m/sec. Dead loads and Wind loads are considered for analysis of the tower using STAAD(X) Tower software which is tailor made for analyzing Telecommunication Towers. It is concluded from this study that Self-Support Towers have lower lateral displacements compared to the Monopole Towers of same height for same amount of loading. This is because they have higher stiffness. But the steel quantity required for Self-Support Towers is about 2 times more than the Monopole Towers for a given tower height, wind speed and loading. However, due to their rigidity, Self-Support Towers have more load carrying capacity than Monopoles. For towers of height below or equal to 40m, Monopoles might be preferred. But, with the increase in height beyond 50m, Self-Support Towers are recommended. This is because, in case of any unexpected and abnormally high wind speeds during cyclones, the structural rigidity will be intact and the damage and repair for the structure may not be so high unlike Monopole.

Keshav Kr. Sharma, et. al. (2015)

In this paper a comparative analysis is being carried out for different three heights of towers i.e., 25m, 35m, 45m using different bracing patterns for Wind zones I to VI and Earthquake zones II to V of India. Gust factor method is used for wind load analysis, modal analysis and response spectrum analysis are used for earthquake loading. In this paper concluded that the wind is the predominate factor in the tower modelling than the seismic forces but the seismic effect cannot be fully neglected as observed from the results and V-Bracing gives satisfactory result in wind analysis, modal analysis and response spectrum analysis for all considered wind and earthquake zones mentioned in IS code. The results of displacement at the top of the towers and stresses in the bottom leg of the towers are compared.

Soltanzadeh, Vafaei et. al. (2014)

Studied seismic performances of ten existing 4-legged telecommunication towers with heights ranging from 18 to 67 meter installed in Iran. For this purpose, three different vertical distributions of lateral load had been utilized. Target displacement approach and design spectrum approach was considered to calculate the seismic performance of towers. It was exhibited that all towers had satisfied immediate occupancy level for both design base earthquake hazard level and maximum probable earthquake hazard level. Also, three equations were presented to estimate towers yield base shear and base shear that corresponds to immediate occupancy level for 4-legged self-supporting telecommunication towers.

Rajasekharan, J. & Vijaya S. et. al. (2014)

Designed the lattice tower for three heights of 30m, 40m and 50m with different types of bracings to study the effect of wind load on 4- legged lattice tower for wind zone V and VI using gust factor method. They also studied the seismic effect on the tower structures by carrying out the modal analysis and response spectrum analysis for zone II to zone V and concluded that the member stresses in bottom leg of XX braced tower are higher as compared to other tower models. The frequency of the tower with Y bracing displayed the least natural frequency since its stiffness was found to be higher due to more weight of the structure as compared to other models. It was observed that from 30m to 40m tower height, the increase in displacement

is nearly linear but as the height increases from 40m to 50m there is a steep increase in the displacement in all the zones.

Hemal J shah & Dr. Atul K Desai (2014)

In this paper a Television towers are constructed to transmit the television signals on the wider areas and this television towers are also used for the purpose of transmitting the radio as well as telecommunication signals. These towers must be properly designed so that they will not fail during the natural disasters such as earthquakes. In past researchers had studied the effect of different earthquakes on 3-legged tall telecommunication towers. In the present study earthquake response of 4 towers of different height are studied considering different bracing system of the tower. The towers of different height are modeled in SAP 2000 software and static and dynamic analysis of the tower has been carried out. In addition to this time history of the bhuj earthquake is applied on all tower and the response of the tower is studied.

Jesumi A., et. al. (2013)

Modelled five steel lattice towers with different bracing configurations such as the X-B, single diagonal, X-X, K and Y bracings for a given range of height. The heights of the towers are 40m and 50m with a base width of 2m and 5m respectively. The tower of height 40 m has 13 panels and the tower of height 50m has 16 panels. 70-72% of the height is provided for the tapered part and 28-30% of the height is provided for the straight part of the tower. The towers have been analyzed for wind loads with STAAD Pro.V8i. 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 50m.

Richa Bhatt, et. al. (2013)

Have carried out study on the influence of modelling in lattice mobile towers under wind loading where in the towers are analysed for gust factor wind. Displacements, Member forces and maximum stress have been compared to find out the effect on towers. In this paper concluded that the wind analysis results showed that irrespective of the tower height modelling strategy does not significantly affect the displacement

pattern, particularly maximum lateral displacement at the top of the tower. Truss model, in general, reflects the lower bound on stresses, irrespective of height, due to dominance of the axial stresses. The bending components normal to the plane of the element are of a lower order. The prototype as fabricated has members which are likely to be subjected to in-plane and out of plane moments. The frame idealization, hence, provides a better estimate of the design forces. Deviations, if any, are easily accounted for by the conventionally adopted factor of safety. The combined model involves more rigorous analysis, whereas the frame model is the safest to adopt due to highest stresses. As the tower height increases, the difference in the stresses among the different idealizations do change, but the generic trend remains the same.

III. FINDING

- Previous researchers observed that self-supporting lattice towers possess higher stiffness and lower lateral displacement compared to monopole towers under wind loading conditions.
- Monopole towers require less construction space and lower material quantity, making them economical and suitable for urban areas with land constraints.
- Wind load is considered the governing factor in the design of telecommunication towers; however, seismic effects cannot be neglected, especially in higher seismic zones.
- Studies revealed that tower height significantly influences displacement, base shear, and member stresses, with displacement increasing rapidly for heights above 40–50 m.
- Different bracing systems such as X, Y, K, and V bracing considerably affect the stiffness and seismic performance of self-supporting towers.
- Dynamic analysis methods such as modal analysis, response spectrum analysis, and time history analysis provide more realistic structural behavior compared to static analysis alone.
- Researchers found that monopole towers generally exhibit higher lateral displacement and lower load carrying capacity than self-supporting towers due to their slender configuration.

IV. RESEARCH GAP

- Most of the available studies focused mainly on wind load analysis, while comparatively fewer investigations addressed the combined impact of wind and earthquake forces on telecommunication towers.
- Limited research has been carried out on direct comparison between monopole and self-supporting towers considering both seismic and wind effects simultaneously.
- Previous investigations mainly concentrated on lattice towers, whereas detailed seismic evaluation of monopole towers is still limited.
- The influence of varying tower geometries, heights, and support configurations on combined lateral displacement and base shear behavior has not been comprehensively studied.
- Few studies validated analytical calculations with finite element analysis (FEA)-based software results for both monopole and self-supporting tower systems.
- Research related to the performance of modern camouflaged monopole towers under dynamic earthquake loading is still insufficient.

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IS Codes

- IS 800: 2007 - Code of Practice General construction in steel?
- IS 875 part I- Dead load
- IS 875 Part II- Live load
- IS 875 Part III- wind load
- IS 875 Part V- load combination