International Journal of Advance and Applied Research
www.ijaar.co.in
ISSN – 2347-7075 Impact Factor – 8.141
Peer Reviewed Bi-Monthly
Vol. 12 No.1 Sept-Oct 2024

Effect of Seismic & Wind Speed on Structural Behavior of Monopole and Self-Support Telecommunication Towers

Mr. Siddhant.D.Shinde-patil[1] Prof. Y. P. Pawar[2] Prof. G. D. Lakade[3]
[1]PG Student, Department of Civil Engineering S.K.N Sinhgad College of Engineering, Pandharpur, India
[2]Assistant Professor, Department of Civil Engineering S.K.N Sinhgad College of Engineering. Pandharpur, India
[3]Assistant Professor, Department of Civil Engineering S.K.N Sinhgad College of Engineering, Pandharpur, India
Corresponding Author- Mr. Siddhant.D.Shinde-patil
Email: siddhantpatil2516@gmail.com
DOI- 10.5281/zenodo.13981942

Abstract:

In recent times, there has been a lot of focus on the telecommunications industry and telecommunication towers due to the exponential rise in the use of mobile phones. These days, everyone carries a mobile phone with them, and as a result, there is a greater need for telecom services. The only way to ensure network reliability and coverage area is through telecommunication towers. Civil engineers evaluate and design the towers that hold up the platforms, telecommunications equipment, panel antennas, and their foundations. Since all of the equipment, including antennas and mounts, is mounted on a tower, civil engineering knowledge is necessary. Tower structural computations consist of wind loads, dead loads, seismic loads, and the design strength of structural steel members on the superstructure, including connections and foundation, are signs of applied loads.

Keywords: staad.pro tower; monopole tower; self-supporting telecommunication tower; lateral displacement

Introduction:

Telecom towers have become essential, especially in the wireless telecommunication industry, with the development of wireless telecommunication technologies as CDMA (Code Division Multiple Access), GSM (Global System for Mobile), WAP (Wireless Web Access), etc.In this context, the majority of telecommunication towers were built in the early 1990s when mobile phone networks were introduced, though a small number of towers have been in operation for more than 30 years. Since India was thought to be earthquake-free until recently, there are thousands of telecommunication towers in this country that have different structural forms. Almost all of these towers have only been designed with wind loading in mind. Nonetheless, given that the country has recently experienced earthquakes with Richter scale readings between three and four, it is important to emphasize the likelihood that the nation will experience earthquakes and to take seismic effects into account when designing buildings and other structures. Due to these advancements, the majority of structural engineers in the nation began to take seismic effects into account when designing buildings, particularly in the building construction industry. However, the designers of telecommunication towers have not yet taken seismic effects into account. Therefore, in terms of sustainable development, a thorough investigation in this area is crucial to guaranteeing the safety of these towers during potential earthquakes in the future.

There are two main reasons why a telecommunication tower failure, particularly during a disaster, is cause for concern. When a tower collapses during a disaster, telecommunications systems fail, which is a major setback for rescue and other critical operations. Furthermore, a tower failure can cause serious financial losses or even fatalities. Therefore, it is crucial to analyze telecom towers under all potential extreme circumstances. The primary goal of this research is to evaluate the performance of exiting towers—which were not originally designed with earthquake loading in mind under potential seismic loading and, in the event that retrofitting is necessary, to identify cost-effective strategies.

Literature Review:

Shehata AY, EI Damatty AA, Savory E.(2005): Despite the fact that extensive research has been carried out on transmission lines subjected to normal wind loads, their behaviour under high intensity wind loads (HIW), such as downburst, is poorly defined. This paper describes a detailed numerical model that can be used to predict the structural performance of a transmission towers as part of a transmission line system under downburst loading. The time history of the downburst wind data is based on a previously developed and validated computational fluid dynamic model. The procedure used to scale the velocity wind data and to transform them to forces is described. The tower members are modeled using three-dimensional linear elastic frame elements, and the conductors and ground wires are modeled using two-dimensional curved beam elements that incorporate geometric non-linearity. A transmission line that suffered previously from significant damage due to a downburst event is then considered as a case study. It is evident from a comparison of the downburst analysis findings with the regular wind results that are usually utilized in the design how important it is to take HIW loads into account when attempting transmission tower structural design.

Sharma K K(2015): The need for wireless and broadcast communication has grown over the past 30 years, which has resulted in a sharp rise in communication tower maintenance and construction. Such structures' failure is a serious worry. This study presents a comparative analysis for wind zones I to VI and earthquake zones II to V in India, considering varying tower heights and bracing schemes. For wind load analysis, the gust factor approach is employed; for earthquake loading, modal analysis and response spectrum analysis are used. A comparison is made between the displacement at the top of the towers and the stresses in the towers' bottom legs.

Silva G S da, Vellasco P C G da S, Andrade S A L de, Oliveira M I R de (2005) : A generalized component-based model for semi-rigid beam-to-column connections, which takes into account the interaction between axial force and bending moment, is presented in this study. The detailed formulation of the proposed analytical model is fully described in this paper, as well as all the analytical expressions used to evaluate the model properties. This paper also presents the numerical results that were generated and validated against experimental tests, a tri-linear approach to characterize the forced-displacement relationship of the joint components, and detailed examples of how to use this model to predict moment-rotation curves for any axial force level.

A bibliographical review containing a brief description of the most important available techniques to predict the joint structural behaviour, using mechanical models, and some experimental tests is also presented.

Glanville M J, Kwok K C S (1995): This paper presents the results of a field measurement program which was conducted on a steel frame tower. Dynamic characteristics of the tower were measured to determine its frequencies of vibration, mode shapes and damping values. A STRAND6 computer model was assembled and confirmed these findings. The dynamic response of the tower under wind loading wasinvestigated before and after the attachment of ancillaries.

Murtagh P J, Basu B, Broderick B M (2004) : This work aims to provide easy approximation techniques for determining natural frequencies and mode shapes of utility towers. A lattice tower with a bulk at the top that represents a utility mounted atop the tower is the structural system under consideration. First, the lumped mass method a model order reduction technique is used to derive the modal features of the tower-mass model. These characteristics are subsequently compared to the corresponding modal properties of the system, found by using finite element analysis (FEA). Results for the first few modes are presented and show close agreement. The system is then modeled by a cantilever beam with a mass at its free end, and the fundamental natural frequency and mode shape are recovered by analytical formulation because the fundamental mode of vibration mostly influences a structure's response. The fundamental mode properties of this approximated system are again compared to the FEA model, and the values are observed to be in close agreement.

Knight GMS, Santhakumar AR. (1993): In transmission-tower analysis, one common assumption is that the joints are pinned. However, because of manufacturing challenges, this expectation is rarely achieved. Consequently, secondary stresses that are not taken into account in the research may actually affect the tower members in actuality. According to the Indian Standard Code of Practice, a full-scale quadrant of the lowest panel of a transmission tower that is intended as a pin-jointed truss is tested under typical load circumstances and the behavior noted is recorded. The test result established that the secondary stresses could be significant enough to cause failure of the leg members even under normal working-load conditions. This paper also deals with the question of whether a transmission tower with secondary braces would be lighter than one designed without these braces. It has been conclusively shown that though the secondary braces increase the number of members, the reduction in stresses in various members leads to a design considerably lighter than the design without these braces. The analysis assumes point joints, whereas the actual tower has bolted connection. This paper brings out the discrepancies between the analysis and actual behavior witnessed during testing.

Wyatt T A. (1984): The practical economic design of lattice towers closely constrains their dynamic features.

It is thus possible to generalize the prediction of dynamic response, using the stochastic wind gust model, with details as outlined in the seminar 'Wind engineering in the eighties' (CIRIA, London, 1980). An approximation to the combined effect of resonant and non-resonant components of the response is presented, as a factor to be applied to the effective stress range based on the dynamic response alone, computed at a single 'reference wind speed'. Results are shown for a variety of useful buildings, and they show that, in general, adequate detailing can guarantee that wind gust fatigue damage does not significantly impair design. It is demonstrated that the normalized results are not very sensitive to changes in tower function, geometry, or location.

Joseph R(2015) : telecommunication towers are lofty buildings that are erected at a particular height and are typically made to accommodate parabolic antennas. The difficult task of designing and building telecommunication towers to reliably withstand all loads in open weather falls to the structural engineer. In our nation, freestanding lattice towers are typically utilized. Recent assessments indicate that by 2020, there will likely be more than 5 lakh mobile towers in India. Locating land for the erection of these traditional lattice towers is quite challenging in densely populated urban areas. Finding a viable, environmentally friendly substitute for traditional lattice towers has become necessary due to land value. Pressures from the environment and the economy have prompted efforts to find better ways to construct communication towers so they are less expensive and more environmentally friendly. Pole structures are a good replacement for lattice towers because they are smaller in size and take up less room when installed. The examination of monopole mobile towers is the focus of the project activity. The software ANSYS finite element is used for analysis. The ANSYS model is utilized to replicate the actions of monopoles functioning as a communication tower. The finite element findings are used to evaluate the monopole tower's efficiency.

Harikrishna P(2003) : Guyed masts are employed in power transmission, wireless communication, and meteorological monitoring. The mast's nonlinear behavior can be attributed to its slim design and obedient "guy-support" system. The guys' potential multimodal excitations and dynamic reaction to wind turbulence also contribute to their non-linear behavior, which is particularly evident at low pretense levels. The measured wind parameters and corresponding dynamic response of a 50 m tall guyed mast situated on India's east coast under ambient wind conditions are presented in this study. A patch load approach proposed by Davenport and Spalding [4] has been compared with the measured root mean square values of displacements. The review examines the suitability of present design practices in light of the full scale experimental findings**.**

Ghodrati A (2007): These days, one of the most important infrastructures in human society is thought to be the telecommunication mast. These structures play a crucial function, so protecting them during natural catastrophes like strong earthquakes is quite important. As a result, their seismic performance needs to be adequately assessed. In their investigations, the researchers primarily focused on the impact of loads caused by wind and earthquakes on the trussed steel masts of triangular cross sections. This paper's primary goal is to examine the 4-legged, self-supporting telecommunication towers' overall seismic reaction.. Ten of Iran's currently operational 4-legged self-supporting telecommunication towers are examined for this purpose, taking into account the effects of the normalized spectra of the Manjil, Tabas, and Naghan earthquakes as well as the design spectrum from the Iranian seismic code of practice. Some of the results showed that, although taking into account the first five modes would improve the analysis precision in the case of taller buildings, the first three flexural modes are sufficient for the dynamic analysis of such towers.

Lanier Keith B.(2009) : This research presents a high-modulus carbon fiber reinforced polymer (CFRP) strengthening method for steel monopole towers. The method is predicated on a theoretical and analytical analysis that involved testing massive steel monopole towers reinforced with various CFRP compositions and interconnection configurations. Design elements and installation methods are presented in light of the research findings. The surface preparation, adhesive application, and CFRP application sequence are all covered in the suggested installation technique.The design aspects are based on flexural elastic analysis and material properties of the CFRP and steel monopole shaft. This paper recommends specific connection details to ensure the development of the forces from the CFRP to the steel tower baseplate.The study's conclusions indicate that CFRP materials offer a workable substitute for steel monopole strengthening, one that can be quickly and simply installed to boost the flexural strength and stiffness of the structure.

Abraham Harikrishna P(2000): The coastal belt of peninsular India, especially the east coast, experiences frequent cyclones. Such cyclones coupled with storm surges cause loss of lives and inflict severe damage to a variety of structures, houses, commercial buildings, industrial structures and many life-line installations. Structural Engineering Research Centre (SERC), Madras, has been conducting post-disaster damage surveys on buildings and structures ravaged by cyclones from time to time. Detailed surveys are undertaken after the occurrence of every severe cyclone in the peninsular India since 1977. A thorough damage assessment of buildings and structures caused by the severe storm that struck the east coast of India in November 1996, close to Kakinada in the Andhra Pradesh State of South India, has been carried out by the Center. The maximum wind speed of the cyclone, as reported by the India Meteorological Department, was about 61 m/s and it was accompanied by storm surges of height upto 5 m. Commonly seen malfunctions include the whole collapse of the roofing system in the majority of residential and semi-engineered buildings consisting of thatch, tiles, and AC sheets; additionally, connections, gable wall failure, and progressive collapse of the roof steel trusses. This study uses photos to demonstrate the harm done to various kinds of constructions.

The paper also suggests simple and useful guidelines to improve the resistance of different structures against cyclonic forces.

Hiramatsu K(1988) : On latticed steel towers with square sections using angle steel, the type of microwave telecommunication towers most commonly used by Nippon Telegraph and Telephone Corporation or N.T.T., a full-scale observation of actual towers was conducted and response characteristics were investigated. The response analysis was performed assuming stationary random process and its reasonableness studied in comparison with the observed results.As a result, the along-wind response and the torsional response can be explained from the response estimation formulas based on stationary approach introduced in this paper. Chen Shen-En Electric transmission pole line systems have complex dynamic characteristics due to unique conductor-pole couplings. Two common transmission poles found in the Southeast of the United States are modeled using finite elements: a prestressed concrete pole and a steel pole. The two poles stand for two distinct structural types: a lightweight, shell-like structure and a heavy, rod-like structure. Simplified numerical models are employed to model the pole line system because coupling concerns between the pole and the cable generate significant complications. To validate the numerical models, a limited set of full-scale modal test results is presented. It is demonstrated that identifying the modes of the prestressed concrete pole is less difficult than that of the steel pole; yet, both numerical models exhibit intricate coupled vibration modes. This research is a component of a bigger project to better understand power grid dynamic response analyses to ground vibrations.

Santhosh Kumar D(2016): With the advance of mobile communication, nowadays, communication network requires telecommunication towers of considerable height to cover the large area of population. Among Monopole, Self-supporting and Guyed, the most commonly used are the self-supporting towers in the field of telecommunication. This research aims to investigate the analysis and design of a basic monopole tower. The study and design of monopole telecom towers are done using two very well-known programs: TNX and STAAD(X) TOWER. In order to build steel towers for transmission and telecommunication, most structural analysis models make the assumption that the steel connections are all hinged and behave like a basic truss. The most often utilized tower geometries, however, have structural mechanisms that can jeopardize the expected structural performance. Rather than the first expected pinned behavior, the semi-rigid response of the connections may provide an explanation for the stability of the system. Using three-dimensional beam and truss finite elements, this work suggests an alternative structural analysis modeling technique for the design of monopole steel towers that takes into account all of the real structural pressures and moments.

N. Prasad Rao(2010): This study describes various kinds of early failures that were found at the Tower Testing and Research Station, Structural Engineering Research Centre, Chennai, during full-scale testing of transmission line towers. Testing-related failures are examined, and the underlying causes are covered in great detail. The impact of isolated hip bracings linked to elevation redundants in "K" and "X" braced panels, as well as non-triangulated hip bracing patterns, on tower behavior are investigated. Plate elements and beam-column elements are used to model the tower parts. Finite element software is used to model different kinds of failures, and the test and analytical findings are compared with different codal provisions.Tower elasto-plastic behavior has been modeled using the non-linear finite element analysis tool NE-NASTRAN. The study examined the significance of secondary member design and connecting details for the tower's overall performance. Non-linear finite element analysis is helpful for predicting failure patterns and ultimate loads as well as for comprehending the behavior of the system. The test results emphasize how important it is to examine the mistakes. It is stressed how important it is to test transmission line towers.

Mohamed Khedr(1999):

When it comes to the seismic analysis of self-supporting telecommunication towers, designers could be inclined to treat these structures like building codes in the lack of precise rules. But unlike shear buildings, these towers react differently to earthquakes. In this study, modal superposition analysis on ten existing towers—each subjected to a set of strong-motion accelerograms acting in the horizontal and vertical directions separately—is used to suggest earthquake amplification factors for the base shear and the total vertical reaction of self-supporting latticed telecommunication towers. Details of the findings are provided for the two towers under investigation, which have heights of 66 and 121 meters, respectively. The base shear and vertical reaction amplification factors are calculated using basic regression analysis of the data. The highest flexural period or longest axial period of vibration of the tower is represented by these parameters, which can be utilized by designers to determine the expected degree of dynamic forces created in self-supporting telecommunication towers as a result of an earthquake.Key words: vertical reaction, base shear, lattice towers, dynamic analysis.

H.A.D.Samith Buddika (2019): The previous several years have seen a massive development in the communication sectors, leading to the installation of numerous towers to improve network consistency and coverage area. These towers are important components of wireless communication networks, so their failure is a big worry. High intensity winds are the primary cause of tower failure, according to numerous studies. Thus, wind design should be given a high factor of safety. In this study, tower base reactions and tower top displacements obtained using code based analysis procedure are compared with the results obtained using the Computational Fluid Dynamics (CFD) simulations. Code-based analysis are carried out according to AS 1170:2 (2002) using MS Tower software. CFD simulations are carried out using MIDAS NFX software. A triangular based lattice tower is used in the study and analysis are carried out for 8 major wind directions. The CFD analysis will be based on 8 major directions of wind and one mean velocity and on the finite method. The case study is intended to provide a support and guidance for the future studies on developing and constructing Towers. In this study we are assuming that super structure of communication tower is linear elastic and only large eddy simulations occurs within the tower region. By using structural design actions code we can calculate the results of the design wind forces and including them in finite element analysis to obtain base reactions and maximum nodal displacements in the tower. By applying real wind profile in the CFD analysis and after getting tower foundation design forces we are going to compare both approaches. Our aim is to optimize the design of telecommunication towers by investigating the effectiveness of CFD analysis for the estimation of tower foundation design forces

Y. P. Pawar, Sandip S. Shevale (October 2016) Earthquakes create vibrations on the ground that are translated into dynamic loads which cause the ground and anything attached to it to vibrate in a complex manner and cause damage to buildings and other structures. Civil engineering is continuously improving ways to cope with this inherent phenomenon. Traditional methods of fortifying the system need greater energy and material use. Moreover, earthquake forces increase with bulk. It has been discovered that alternative tactics, including passive control systems, are useful in lessening the dynamic effects of earthquakes and other events on civil engineering projects. A device called a tuned mass damper (TMD) is fastened to a structure in order to lessen the dynamic response of the structure. It consists of a mass and a spring. It has been discovered that the most efficient method for regulating the structural responses to wind and harmonic excitations is the tuned mass damper (TMD). These days, base isolation is frequently regarded as a successful tactic to safeguard buildings against seismic shocks. Investigated is the effectiveness of a tuned mass damper and a linear base isolation device in reducing the seismic response of buildings.

Priyanka V.Galande, Prof. Y.P. Pawar(2021). Typically, chimneys are made to withstand loads brought on by wind and seismic activity. Therefore, it is essential to analyze the chimney's dynamic response to the effects of wind and seismic stresses. The chimney's altered geometry makes structural analysis—such as how it will react to an earthquake—more important. This research primarily focuses on performing a seismic analysis of a chimney made of reinforced concrete. The primary goal is to investigate how diverse factors, such as different seismic zones and chimney soil conditions, affect the structure's ability to withstand earthquakes.

Gaurav Gaikwad, G. D. Lakade, C.P.Pise (2019). When the phrase "vibrations" is used in relation to flooring, it means that the building and its occupants experience oscillatory motion while doing their regular daily tasks. Although it is typically vertical (up and down), vibrations can also occur horizontally. In a different situation, the effects of vibrations might range from bothering building occupants to harming fixtures and fittings or, in extremely rare circumstances, even the building structure itself. A mechanical phenomena known as vibration is the oscillation of a mass. Vibration comes in two flavors: forced vibration and free vibration.Most often, dynamic loads—applied directly to the floor by people or machinery—cause vibrations in floors. The best way to address vibrations caused by machinery is to use motion arresting pads or isolating mounts at the source.

Because of their size and the way they work, factory-installed machinery typically causes the most intense vibrations. But in most factories, floor vibration is rarely an issue because workers accept it as a necessary component of the industrial setting. The operating conditions of mechanical equipment, particularly for predictive maintenance, should be based on the rigorous control of vibrations of mechanical equipment, such as rotating machinery, in accordance with the application and criteria of current technical standards as well as those that are still being studied. At an early stage in the design process it is possible to locate both rhythmic activities and sensitive occupancy so as to minimize potential vibration problems and the costs required to avoid them. It is also a good idea at this stage to consider alternative structural solutions to prevent vibration problems. These structural remedies could involve the building's structure being designed to regulate accelerations as well as unique techniques like isolating the activity floor from the rest of the structure or utilizing mitigating tools like tuned mass dampers.

Key finding :

Depending on their structural makeup and design, monopole and self-support telecommunication towers behave quite differently during seismic activity and in relation to wind speed. Several important inferences can be made from their structural behavior, as follows:

Seismic Events:

Monopole Towers: Usually feature more straightforward designs and, because of their single-pole structure, are more vulnerable to lateral stresses during seismic occurrences. The design of the foundation and the state of the soil have a major impact on the response.

Self-Support Towers: The guyed or lattice structure of these towers can disperse seismic energy more effectively and offer greater flexibility, but the integrity of joints and connections also plays a role in how these structures respond to earthquakes.

Wind Speed:

Monopole Towers: Compared to self-support towers, they often feature a more aerodynamic shape that lessens vibrations and oscillations caused by wind. In order to sustain wind loads without suffering considerable distortion, proper detailing and material selection are essential.

Self-Support Towers: Compared to monopoles, lattice or guyed constructions provide less resistance against wind forces. To reduce dynamic impacts, their reaction can be controlled via structural bracing and suitable design.

Design Considerations:

To make sure that both kinds of towers can survive expected seismic events and wind speeds, careful consideration of material strength, foundation design, and dynamic load analysis (including modal analysis) is needed.

Self-support towers depend on strong bracing and structural connections to be stable, whereas monopole towers benefit from streamlined designs that lessen the impacts of wind load.

Maintenance and Inspection:

For both types of towers, routine maintenance and inspection are essential to ensuring structural integrity over time. This entails keeping an eye out for any indications of structural deterioration, fatigue, or corrosion that can impair functionality during earthquakes or strong winds.

In conclusion, monopole and self-support telecommunication towers have different unique structural behaviors because of their design and construction features, even if they can both be made to endure wind speeds and seismic events. In order to maximize performance and guarantee safety in a variety of environmental circumstances, engineers must customize their design methodologies to these particular aspects.

Acknowledgment:

We would like to extend our sincere thanks to everyone at the Department of Civil Engineering for their generous assistance and support throughout our project. Our heartfelt gratitude goes to our project mentors, who skilfully guided us and provided the encouragement needed to pursue our objectives and bring this project to fruition. Therefore, we express our profound thanks to Dr. Y.P.Pawar and Prof. G.D.Lakade for their invaluable guidance and unwavering motivation at every stage of our endeavour

References:

1. Jatwa H. Comparative study of Indian and ASCE codes provision for design of transmission tower, International Journal of Innovations in Engineering and Technology, 4(2014) 18-29.
2. Sharma K K, Duggal S K. Comparative analysis of steel telecommunication tower subjected to seismic & wind loading, Civil Engineering and Urban Planning:An International Journal (CiVEJ), 2(2015) 15-33.
3. Joseph R, Varghese J. Analysis of monopole communication tower, International Journal of Engineering Studies and Technical Approach, 1(2015) 23-34.
4. Amiri G, Boostan A. Dynamic response of antenna-supporting structures, 4th Structural Specialty Conference of the Canadian Society for Civil Engineering, (2002) pp. 1-9.
5. McClure G, Georgi L, Assi R. Seismic considerations for telecommunication towers mounted on building rooftop, 13th World Conference on Earthquake Engineering, Vancouver, Canada, Paper No. 1988, 2004.
6. Abraham Harikrishna P, Gomathinayagam S, Lakshmanan N. Failure investigation of microwave towers during cyclones A case study, Journal of Structural Engineering, 32(2005) 147-57.
7. Ghodrati A. Seismic behaviour of 4-legged self-

supporting telecommunication towers, World Applied Sciences Journal, 2(2007) 1818-4952.
8. Lanier Keith B. Study in the improvement in strength and stiffness capacity of steel multi-sided monopole towers utilizing carbon fiber reinforced polymers as a retrofitting mechanism,Thin-Walled Structures,(2009) 1037-47.
9. Prasad Rao N, Samuel Knight G M, Lakshmanan N, R Iyer N. Investigation of transmission line tower failures, Engineering Failure Analysis, 17(2010) 1127-41.
10. Shehata AY, EI Damatty AA, Savory E. Finite element modeling of transmission line under down burst wind loading, Finite Elements in Analysis and Design, 42(2005) 71-89.
11. Silva G S da, Vellasco P C G da S, Andrade S A L de, Oliveira M I R de. Structural assessment of current steel design models for transmission and telecommunication towers, Journal of Constructional Steel Research, 61(2005) 1108-34
12. Harikrishna P, Annadurai A, Gomathinayagam S, Laxman N. Full scale measurements of the structural response of a 50 m guyed mast under wind loading, Engineering Structures, 25(2003) 859-67.
13. Hiramatsu K, Akagi H. The response of latticed steel towers due to the action of wind, Journal of Wind Engineering and Industrial Aerodynamics, 30(1988) 7-16.
14. Kashid, M. M., Karande, K. J., & Mulani, A. O. (2022, November). IoT-based environmental parameter monitoring using machine learning approach. In Proceedings of the International Conference on Cognitive and Intelligent Computing: ICCIC 2021, Volume 1 (pp. 43-51). Singapore: Springer Nature Singapore.
15. M.J. Glanville Dynamic characteristics and wind induced response of a steel frame tower February 1995
16. P.J Murtagh Simple models for natural frequencies and mode shapes of towers supporting utilities August 2004
17. G. Knight Joint Effects on Behavior of Transmission Towers 1 March 1993
18. T.A. Wyatt An assessment of the sensitivity of lattice towers to fatigue induced by wind gusts October 1984
19. Santhosh Kumar D. Analysis Of Monopole Telecommunication Tower (2016)
20. Riya Joseph, Jobil Varghese, Analysis of Monopole Communication Tower (2015)
21. B.Lanier, ―Behavior of steel monopoles strengthened with high-modulus CFRP materials‖, Journal of thin walled structures, 2009
22. Shen-En Chen, ―Modal characteristics of two operating power transmission poles‖, Department of Civil and Environmental Engineering, University of North Carolina, 2010.
23. Gaurav Gaikwad, G. D. Lakade, C.P.Pise (2019).
24. Analysis and Design of Steel Frame Structure for Rotating Motors.
25. DCP Pise, SS Kadam, YP Pawar, DD Mohite Performance-Based Seismic Design of Structures.. International Journal of Scientific Research, 2015
26. Mohamed Khedr Earthquake amplification factors for self-supporting telecommunication towers February 2011
27. Brian Broderick Simple models for natural frequencies and mode shapes of towers supporting utilities August 2004
28. H.A.D.Samith Buddika Wind effect on structural behavior of telecommunication tower January 2019
29. Joyson SILVA . P Effect of Wind and Earthquake Loading on Telecommunication Tower November 2019
30. GD Lakade, DCP Pise, SS Kadam, YP Pawar, D Mohite, CM Deshmukh Performance of RC Building under Dynamic Forces and Suitability of Strengthening by FRP Jacketing International Journal of Civil Engineering and Technology 6 (9), 2015,
31. Y. P. Pawar, Sandip S. Shevale (October 2016). "Seismic Behaviour of Multi-Storied Building by. Using Tuned Mass Damper and Base Isolation: A Review"