Design & Analysis of Light Mast Tower: A Review

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Abstract-Light mast towers are installed in almost all the mines to continue the required task throughout day. Majority of the mines in India uses these light mast towers which are stationary. Some of the light masts can be tilted about the horizontal axis by a very small angle. This enforces the restriction on the usage of these light masts. In this research designing of a new mechanism is proposed which will provide various rotations to the light mast which will increase its usability considerably. The proposed mechanism can rotate each light about its horizontal as well as vertical axes. However the entire light mast can be rotated about its vertical axis. In the present review performance parameters of tower design are evaluated and the causes of failures in the tower design are studied.

Keywords: *Mechanized Light Mast tower, wind load, wind shear*

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1. INTRODUCTION

High-mast lighting towers are vertical, cantilevered structures that are used to illuminate a relatively large area. Although primarily used for highway intersection lighting in rural areas, open cast and underground mines, they are also utilized in other large areas such as parking lots, sporting venues, or even penitentiaries. As a result, failures of these structures are critical due to the potential for them to fall across highway lanes or other occupied areas. High-mast lighting dates back to the 1800's when tall masts were installed in several cities to illuminate large areas.

1.1. Features of Light Mast Towers

High-mast lighting towers have several distinct features. The towers consist of a single sectioned tube connected to a flat base plate. The base plate is bolted to a concrete foundation that extends several feet into the ground. Illumination comes from a lighting apparatus located at the top of the tower. The concrete foundation extends several feet into the ground, depending on local geological conditions. Anchor rods are used to connect the high-mast base plate to the concrete foundation. The size and number of anchor rods used are determined by the size and height of the high-mast tower. The anchor rods extend into the concrete foundation a considerable depth to prevent anchorage failure. Nuts are used on both the top and bottom of the tower base plate. Leveling nuts are used underneath the base plate to both level the tower during erection and provide uniform tightening of the base plate. The top nuts tighten the base plate to the leveling nuts which fixes the entire system to the concrete foundation. It is important to note that improper tightening of the nuts can introduce additional stresses in the pole to base plate connections.

2. LITERATURE REVIEW

2.1. Helin Zhou has revealed that, Towers on mountaintops have more incidence of lightning than towers on the flat ground. Therefore towers on mountaintops are ascribed an effective height that is often considerably larger than the physical height of the tower. This will evaluate the definitions and methods that could be used to estimate the effective height of a given tower on mountaintop and propose a new definition based on an engineering model of lightning attachment. The results can be useful in designing lightning protection of communication/transmission lines and masts on mountaintops.
According to his study,
1) Pierce was the first to estimate the effective height of the Berger's tower. The tower had a physical height of 70 m and it was on the top of a 640 m tall mountain. The effective height of this tower was estimated to be 270 m. Pierce's estimate was based on the observed higher lightning incidence to the mountaintop towers compared to similar towers on the flat ground.
2) Eriksson's approach is based on the observed percentage of the upward flashes initiated from towers of different height.
3) Rizk's model is applied for the estimation of effective height of structures on mountaintops. This model predicts effective heights that are less than those predicted by the Pierce and Eriksson methods, although definitions of effective height in the three methods are somewhat different from each other. It is shown that the effective height depends primarily on the structure height, mountain shape, and upward positive leader speed. When the tower height is less than 20% of the mountain height, the effective height is largely determined by the physical height of the tower and the mountain shape.

Table 1.Effective height of structure on mountaintops

Object and location	Tower height in	Mountain ht.in Meter	Pierce method	Eriksson method	Rizks Method
Switzerland	**70**	**640**	**270**	**350**	**198**
Northern side	**40**	**990**	**NA**	**500**	**120**
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South Africa	**60**	**80**	**NA**	**148**	**113**
Germany	**160**	**288**	**NA**	**NA**	**324**
Brazil	**248**	**493**	**NA**	**NA**	**468**

2.2. Maria Repetto proposes a mathematical model aimed at deriving a histogram of the stress cycles, the accumulated damage and the fatigue life of slender vertical structures in along wind vibrations. The formulation, integrally in closed form, is based on a probabilistic counting cycle method inspired by narrow-band processes. The paper formulates a mathematical method for the fatigue analysis of slender vertical structures subjected to gust-excited along wind vibrations. The method, integrally in closed form and simple to apply, leads to analytical expressions of the cycle histogram, of the total damage and the fatigue life. It supplies relevant elements for the comprehension of the physical phenomenon and is particularly suited to the engineering applications in the structural field. The comparison between the analytical solutions and the numerical simulations emphasizes on the time domain approach.
2.3.P. Harikrishna studied the behavior of the guyed masts which are used for wireless communication, meteorological measurements, and recently, even for power transmission. The behavior of the mast is non-linear due to its slenderness and compliant 'guy-support' system. The guys also exhibit nonlinear behavior especially at low values of pretension due to possible multimodal excitations and dynamic response to wind turbulence. This study provides the results of measured wind characteristics and associated dynamic response of a 50 m tall guyed mast located on the east coast of India in ambient wind conditions. The measured root mean square values of displacements have been compared with a patch load method suggested by Davenport, during the measured wind speed range. The dynamic response of a 50 m tall guyed mast which is located on the east coast of India, under normal wind is experimentally and analytically investigated. The estimated power law coefficient and terrain roughness length comply with that of an open terrain as observed in the field. The turbulence intensities in the measured wind direction (south-west) remained steady at each level with marginal fluctuations

2.4. Gregory M. Hensley gives the response of a 120 m-tall guyed mast to three-dimensional seismic excitation which is analyzed using the finite-element program Abaqus. The mast is pinned at its base, and guy cables are attached at four equally spaced points along its height. The dynamic tension in the guys is modeled by a nonlinear function based on tests, and periods of slackness in the guys during motion of the system lead to snap tension loads and affect the response. The mast is represented by three-dimensional beam elements. Displacements, bending moments, and base shears are computed for the mast, along with guy tensions. The effects of guy stiffness and pre-tension, mast weight, and directionality of the ground motion are investigated.

1) A finite-element analysis of a 120 m-tall guyed mast, pinned at its base, has been conducted in this study. Large responses were computed, and the guy wires, attached at four equally spaced levels of the mast, exhibited periods of slackness followed by snap loads with a sharp rise in tension.

2) When in tension, the guy force was assumed to be a nonlinear function of the elongation, based on vibration tests on synthetic fiber ropes. The assumed stiffening behavior also should be relevant for some guy cables made of other materials.

2.5. M. Belloli compares the wind loads measured experimentally in wind tunnel tests and those predicted by Eurocode on a high slender tower with a porous external surface forming an intricate three-dimensional spiral. In the experimental tests a rigid and an aeroelastic model of the tower were tested in low and high turbulent flow conditions. The aim of the wind tunnel tests was to evaluate the wind actions at the base of the structure and, comparing the results from the two models, to verify the presence of possible aerodynamic effects, such as force fields due to fluid–structure interaction. The along wind dynamic response of the tower calculated experimentally was then compared with the results obtained numerically using Euro code, under the hypothesis of negligible aero elastic effects. The wind actions on a high slender tower with a highly three dimensional external porous surface have been investigated. Tests in low and high turbulent flow using a rigid and an aero elastic model enabled a full study and comparison in terms of global wind loads at the base of the spire, taking into account also the inertial effects.

2.6. Flavia De focuses on the modal dynamic identification, in situ inspections and testing which provides the necessary knowledge of the structure in terms of geometry, structural details, and material properties. Two nonlinear models of the structure are built up in both the hypotheses of accounting and not accounting for stiffness and strength contribution. Lumped plasticity model for reinforced concrete elements and equivalent strut macro-models for tuff and concrete infills are employed. Seismic assessment through nonlinear dynamic analyses is carried out for both limit states of Significant Damage and Damage Limitation. Assessment of bare and infilled models emphasizes a lower demand in terms of maximum interstorey drift of the infilled model with respect to the bare model, for both limit states considered. Record-to-record variability for the sets of seven records becomes larger if in fills strength and stiffness contribution is taken into account. Outcome of the assessment is not affected by in fills, i.e. the structure can be considered safe (according to EC8 provisions) for both limit states, and in both modeling hypotheses. On the other hand, the ratio demand over capacity, for both the limit states considered, is strictly influenced by in fills' contribution.

The capacities are evaluated as per EC8 definitions for both bare and infills structure. Seismic analysis of both bare and infills structure indicates that,

1) Lower demand in terms of maximum interstorey drift of the infilled model with respect to the bare, for both limit states considered. Scattering around the mean values evaluated on the sets of seven records becomes significantly larger if infill contribution is taken into account.

2) outcome of the assessment is not affected by infills, i.e. the structure can be considered safe for both limit states, and in both modeling hypotheses. On the other hand, the ratio demand over capacity, for both the limit states considered, is strictly influenced by infills' contribution.

Finally, results highlights that tuff masonry infill increases stiffness and strength of the structure as long as the seismic demand does not exceed the deformation capacity of the infills; after that, both global stiffness and global strength deteriorate. On the other hand, displacement profiles show that tuff infills provide a regularization of demand along the height of the building. Therefore, nonstructural elements contribution still plays a significant role in the assessment.

2.7. Lasse Makkonen determine ice load as a major design criterion of tall towers. International Standard ISO 12494 gives a method to assess ice loads and combined ice and wind loads on complex structures by Ice Classes. The method has not been directly verified, however, this study presents an analysis of the applicability of the ISO method based on field data on rime icing. The data include ice amounts simultaneously measured on the ISO Standard ice collector, a 7.5 m tall self-supported lattice structure and a 127 m tall guyed lattice TV-tower. Ice masses are compared on these objects within specific Ice Classes and calculate the ice masses calculated for the structures based on the ISO method. The results show that ISO Ice Classes are a useful tool in assessing rime ice loads on structures, but that systematic errors arise. These errors tend to be on the safe side in regard to structural design and are, at least partly, related to poorly known ice shedding mechanisms.

2.8. Massimiliano Lucchesi proposes a numerical model is to enable performing non-linear dynamic analysis of slender masonry structures and elements, such as towers and columns or masonry walls in out-of-plane flexure. Such structures are represented via a continuous one dimensional model. The main mechanical characteristics of the material in all sections along the height of such structures are taken into account by means of a non-linear elastic constitutive law formulated in terms of generalized stress and strain, under the assumption that the material has no resistance to tension and limited compressive strength. The relations defined herein for the general case of hollow rectangular cross-sections are also aimed at enabling study of towers, bell-towers and similar slender structures. The numerical model presented herein allows for conducting non-linear dynamic analyses of slender masonry structures with primarily flexural behavior, such as free standing towers, columns or masonry walls in out-of-plane bending. In developing the model, we have formulated a constitutive equation for beams with hollow, rectangular cross-sections made of material with no resistance to tension and limited compressive strength. Although the model is able to account for the material's non-linear behavior, it is nonetheless simple enough to enable conducting dynamic analysis relatively quickly with modest computational resources. Moreover, it is general enough to allow predicting the behavioral response of slender masonry structures with varying end constraints, subjected to both horizontal and vertical dynamic excitations and different load conditions, including their own weight.

2.9. Neil I. Fox summarizes the results of a study of wind speeds observed at heights up to 150 m above ground level around Missouri. This is an amalgamation of four projects that allowed a total of eleven tall communication towers to be instrumented with wind observation equipment across the State of Missouri. This provided an assessment of the wind resource and the characteristics of the seasonal and diurnal cycles of wind in different areas of Missouri at the heights of utility scale wind turbines. Comparisons were also made to wind speeds predicted at these levels from a previously published wind map.

The main finding was that, the observed winds at each tower were smaller than those presented in the wind map. The discrepancy is most likely to be due to underestimation of the surface roughness and turbulence leading to an overestimation of near-surface wind shear. However, the wind shear, as expressed by the shear parameter was consistently greater than the 'standard' value of 1.4.

The reconciliation of these two apparently contradictory findings is that the shear varies with the height at which it is measured. In wind resource assessment, wind shear is usually observed below 50 m and is tacitly assumed to be constant with height when used to extrapolate winds to higher levels. The author advocates the use of the friction velocity as a measure of shear in wind power applications in preference to the shear parameter that is usually used. This is because the shear parameter has a velocity bias that can also

manifest as a bias with height or season. As wind power resource assessment is starting to use taller towers than the standard 50 m, inter comparison of site resources and extrapolation to turbine heights can be compromised if the shear parameter is used.
In general, the changes in shear with time of day ,season, location and height are complex, and there are a number of contributing factors. One factor that impacts the interpretation is the choice of shear parameter. As the shear parameter tends to increase with smaller wind speeds one would expect to see larger values during the summer, closer to the surface and during the day. This appears to be the case for the first two (with southerly winds being correlated with summer periods, there are also generally greater values of a seen with more southerly winds), but this is not the case at night. This is most likely because the increased atmospheric stability creating genuinely larger wind shear at night dominates over the effect of greater wind speeds on the value of the shear parameter.

3. CONCLUSION

This paper provides the details of the research work which has been carried out in the field of light mast tower designing under various conditions. This light mast tower is a very crucial element of any mine. The proposed mechanism is allowed to rotate the lights which are mounted on the tower about its vertical & horizontal direction. When the light mast rotated about horizontal axis by 90^o, we can focus the light in the vertical plane. This will enable the light exactly beneath the tower. When the light mast is rotated about vertical axis by 180^o, we can focus the light in the horizontal plane. Using this motion we can focus the light away from the tower horizontally. By setting lights using these operations, we can rotate the entire light mast assembly by 360^o which will enable the light around the tower.

These operations which are incorporated in the design can hold maximum of eight lights in the any required position without any jerk & over stressed conditions in operation.

4. REFERENCES

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