

# Design, Modeling & Analysis of A Light Mast Tower

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**Abstract:** *Lighting is a major requirement when we deal with working inside a mine whether it is Underground or Opencast mining. In opencast mining efficient lighting system is required while working during dark hours. In underground mining a very efficient lighting system is required when worked underground hours for whole day long. In the present work a new system of light mast tower is proposed & designed which increases the usability of the existing light mast towers. In this new system, each light of the light mast is given a rotation about its vertical & horizontal axis which enables the light to focus at any particular direction & position without disturbing the other lights in use. In addition to this 360° rotation about the vertical axis which enables the user to provide the light source at multiple positions.*

**Keywords:** Mechanized Light Mast tower, wind load, wind shear, High mast light towers

## 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, 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. The first known application of high-mast lighting to highways was the Heerdter Triangle installation in Dusseldorf, Germany, in the late 1950's. It was followed by installations in other European countries including Holland, France, Italy, and Great Britain. With the passing of the Federal Aid Highway Act of 1956, interest in high-mast lighting in this country was stimulated by the successful applications in Europe.

In the late 1960's, studies were conducted to investigate the impact that high-mast lighting has on driver visibility, traffic performance, and illumination costs. It was found that increasing the height of the lighting offered a noticeable advantage in that it provided drivers with increased uniformity of illumination and brightness while minimizing discomfort and disability glare. This, in turn, led to a reduced number of visibility related accidents.

### Features of a 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. Base plates range from 1.5-in to 4-in in thickness. 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.

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. This is believed to be the culprit of many high-mast tower failures. In order to prevent loosening of the top nuts, double nuts are commonly used on the top side of the base plate.

## 2. Literature Survey

Helin Zhou et al. have revealed the Towers on mountaintops have more incidence of lightning than towers on the flat ground 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.

#### **Maria Pia Repetto, Giovanni Solari**

The wind-excited vibrations of structures induce fluctuating stresses around mean deformation states that lead to fatigue damage accumulation and can determine structural failure without exceeding design wind actions. This paper 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. This 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.

#### **P. Harikrishna, A. Annadurai, S. Gomathinayagam, N. Lakshmanan:**

Guyed masts 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 behaviour especially at low values of pretension due to possible multimodal excitations and dynamic response to wind turbulence. This paper presents 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 and Spalding.

#### **M. Belloli, L. Rosa, A. Zasso**

This paper 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 simplified CAD Model of Mechanism consisting of a Leadscrew, Gearbox and Plummer block is as shown in the

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.

#### **Massimiliano Lucchesi, Barbara Pintucchi**

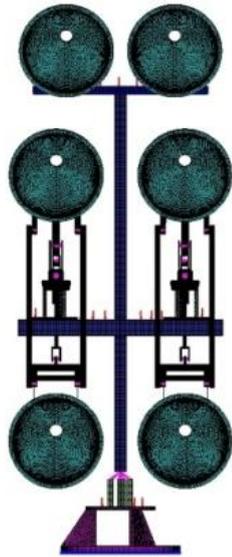
A numerical model is presented to enable performing non-linear dynamic analysis of slender masonry structures and elements, such as towers and columns or masonry walls in out-of-plane flexure. Such structures are represented via a continuous one dimensional model. The main mechanical characteristics 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.

#### **Modeling of a light mast tower:**

In earlier times wherein computers were not yet developed, there has been a representation of using conventional media in designing. Ancient architects used text to abstractly describe the design process. 2D drawings were later introduced and only expressed abstract visual thinking. The attempts have been continued to identify the nature of different design tools. The 3D model is created using the solid works software. Basically the frame is modeled first and the outline provides the basic idea of a complete model. The dome shaped lights are created in 2D and then extruded by using pan command. Once a single dome is created that can be mirrored as per the requirement. Now for the modeling the designed mechanism separate assemblies are created. The worm and worm gear is drawn and also the leadscrew arrangement is created. Finally the assembly of all the components is done and the complete 3D model is created finally. As the objective of this project is to provide movement to the lights of light mast tower, the mechanism is proposed which consist of the gearbox driven by the single phase induction motor of rpm. The gearbox consist of worm gears. Worm gear drives are used to transmit motion and power between two mutually perpendicular non-intersecting axes with large reduction in a single step.

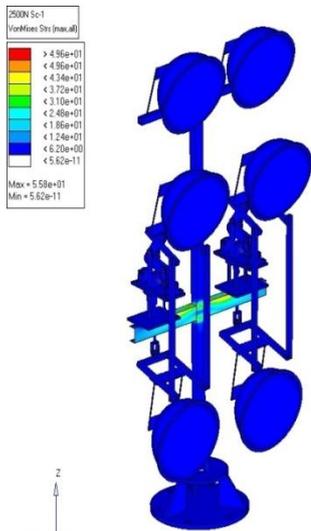
figure, The set of worm gear and motor is used to rotate the whole assembly in clockwise as well as anticlockwise direction. The motor used, is a single phase induction motor of 1550 rpm and the worm and worm gear size is designed for the particular application. The whole assembly is mounted at the base from where the pole is initiated. The worm gears used are having their velocity ratio as 1440:40 in single step of reduction. The linkage arrangement is basically used for the movement of lights about their vertical and horizontal direction. The leadscrew with a pitch length of 10 mm is mounted on the frame which is constrained to move in vertical direction using the Plummer block from both the ends. The motor used is a single phase induction motor of 1440 rpm and is used to rotate the leadscrew. The leadscrew is equipped with a nut and the nut is pivoted by the two linkages used to provide a free movement to the linkages of dome shaped lights. Similarly the frame is arranged with the gearbox and motor assembly used to rotate the lights in particular direction.

### FEA Analysis



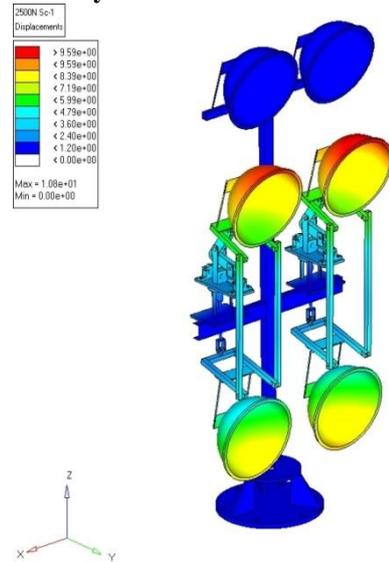
Meshing is basically discretization, in which the whole geometry is divided into number of regular geometries. In 2D FE modeling, if there is a choice between triangles and quadrilaterals with similar nodal arrangement prefer quadrilaterals. Triangles are quite convenient for mesh generation, mesh transitions, rounding up corners. The 3D element selected is hexahedron. The meshing type used for the 2D element is surface meshing and for 3D element volume meshing is done. Total elements in the meshing model of light mast tower are 2 64,580 and the corresponding nodes in the meshed model of the light mast tower are 2, 67, 279.

### Stress Analysis



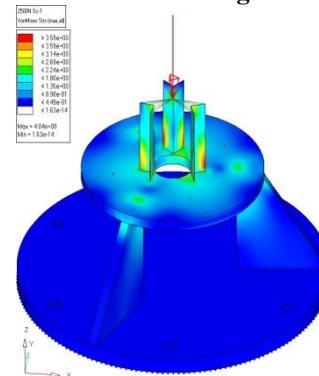
The results of the stress analysis of a complete light mast tower reveal that the maximum stress occurs in the frame where the overall mechanism for the movement of the dome lights is mounted. The maximum stress value is 55 mpa and the allowable stress of the M.S material is 200 mpa. Therefore, we can conclude that the design is safe enough for its application and working. If the stress will increase beyond the allowable stress of the material then their occurs a failure.

### Displacement Analysis



Since the lights of the light mast tower will move in the particular direction then, there is possibility of excessive displacement caused due to the heavy mechanism of the Gearbox and leadscrew assembly. The maximum displacement recorded is nearly equal to 10 mm for the domes of light mast tower which is negligible as the total height of assembly is 30 cm which is quite large compared to the displacement recorded for the lights. Hence , we can conclude that the structure is safe in the case of displacement analysis.

### Stress Analysis of Journal Bearing



The journal bearing is the most important part of the whole assembly as the total weight of the assembly is concentrated on the journal bearing. Considering the total weight of assembly the stress analysis for the journal bearing is carried out and the results are observes as , The maximum stress acting on the supports is equal to 4mpa so the bearing design is safe.

### 3. Conclusion

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°, 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°, 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° 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.

Department of Safety and Engineering Branch and Staff Bridge Branch (2006).

[16] Jang, J. J., "Analysis of reliability of dynamic of the wind structure," *the Seventh Structure Engineering Seminars* (2004).

## References

- [1] Helin Zhou "On estimation of the effective height of towers on mountaintops in lightning incidence studies", *Journal of Electrostatics*, vol.68, 2010, 415-418.
- [2] Pia Repetto, "Dynamic along wind fatigue of slender vertical structures", *International Journal on engineering structures*, vol.23, 2001, 1622-1623.
- [3] P. Harikrishna, A Annadurai, A. Gomathinayagam, N Lakshamanan, "Full scale measurements of the structural response of a 50 m guyed mast under wind loading", *Research paper*, vol.25, Dec 2002, 859-867.
- [4] Gregory M. Hensley, Raymond H. Plaut, "Three-dimensional analysis of the seismic response of guyed masts", *International Journal on engineering structures*, vol.29, 2007, 2254-2261.
- [5] M. Belloli, "Wind loads on a high slender tower: Numerical and experimental comparison", *International Journal of engineering structures*, vol.68, 2014, 24-32.
- [6] Lasse Mkonen, Pertti Lehtone, Mika Hirviniemi, "Determining ice loads for tower structure design", *International Journal of engineering structures*, vol.74, 2014, 229-232.
- [7] Massimiliano Lucchesi, "A numerical model for non-linear dynamic analysis of slender masonry structures", vol.68, 2006, 24-32.
- [8] Neil I. Fox, "A tall tower study of Missouri winds", *International Journal of Renewable Energy*, vol.36, 2011, 330-337.
- [9] Cello F. Carri "Experimental Study of The Wind Forces on Rectangular Lattice Communication Towers with Antennas" *Journal of Wind Engineering and Industrial Aerodynamics*, vol. 91. 1007-1022.
- [10] Simiu, E., Scanlan, R., "Wind Effects on Structures: Fundamentals and Applications to Design", *John Third Edition Wiley & Sons*, New York, 1996
- [11] Sockel, H., "Wind-Excited Vibrations of Structures". CISM Courses and Lectures NO. 335, *International Centre for Mechanical Sciences*, 1994.
- [12] Chien, C. W. and Jang, J. J., "Wind-resistant design of high mast structures," *Asia Pacific of Engineering Science and Technology*, Vol. 3, No. 2, (2005).
- [13] Davenport, A. G., "The interaction of wind and structures," in: E. Plate (Ed), *Engineering Meteorology*, Elsevier Scientific Publishing Company, Amsterdam, (1982).
- [14] Melbourne, W. H., "Predicting the across-wind response of masts and structure members," *Journal of the Wind Engineering and Industrial Aerodynamics*, No. 69-71, pp. 91-103 (1997).
- [15] Lindt, J. W. van de and Goode, J. S., "Development of a Reliability-based Design Procedure for High-Mast Lighting Structural Supports in Colorado", Colorado