Methodology for Design and Analysis of High Mast Solar Light Pole – A Review

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Abstract— This paper reports on a long-term in-depth field experimental study on the behavior and dynamic response of high-mast lighting structures being conducted in response to recent static Loading failures. The initial results of the study and suggested strategies for design, inspection and maintenance of these fracture critical structures are summarized.

Key words: Fatigue, High-mast Lighting, Wind, Forensic Investigation

I. INTRODUCTION

The modern High Mast Structure (HMS) originated nearly at the beginning of the 20th century. Typically, from data a functional utility on the tip of the structure such as a wind-force turbine, a radiowave transmitter, a radar, or some lamps and lanterns.Up to today, different configurations of tubular HMS have been used widely in modern civil construction. The unit costs of these structures are low, however, their designs may cause problems (Solaria, 1999). In the past years, many accidents and much damage have been caused by strong wind or wind-induced vibrations in such structures. These frequent accidents confirm the necessity for a better understanding about HMSs' geometric configurations and structural properties, and also the necessity to develop wind-resistant design criteria for HMS for these of designers. the first focus on geometric configurations and shape factors to compare the different codes. Then, the structural and geometric properties of existing High Mast Lighting Structures (HMLS) in Taiwan are investigated to obtain the Wind resistance design criteria and procedures.

The wind resistance design criteria for high mast structure include two objectives. One is to define the identification of a yield criterion and the strength limitation of the support structure. The other is to provide uninterrupted service by the tip utilities under extreme wind. By using computational design, this study finds that the drag coefficients of an 8 or a 16-sided pole for uniform and shear flows.

A desk-top investigation was subsequently undertaken to review the fatigue and ultimate strengths of the light poles, anchor bolts, and foundations in order to decide whether repair or replacement of the poles would provide the lowest whole-of-life cost. As a result of this investigation it was decided to repair the light poles, with modified details to extend their fatigue life.

Wind force is the main consideration for the HMS design, which is affected by the shape factor, projected area, and angle of attack. Therefore, geometric configuration has an important influence on wind load. Usually, this influence can be measured by means of field measurement or wind tunnel test.

This paper describes the investigations that were undertaken, and the recommended modifications that would reduce the stress concentration in the pole mast, and hence extend the fatigue life.

As the project is being done in collaboration with SAMEER SOLAR, the Static Analysis is carried on High Mast solar light pole.

II. EARLIER WORK ON HIGH MAST SOLAR LIGHT POLE

The Iowa Department of Transportation (DOT) owns 233 high-mast lighting towers ranging from 100 to 180 feet tall. These multi-sided poles were constructed between 1970 and 2001. One hundred ninety-seven of these poles are made from weathering steel; the remaining 36 are galvanized, which were constructed in years 2000 and 2001. A statewide inspection in year 2000 was conducted on 193 of the towers in the inventory.

Fig. 1: Photograph of collapsed high mast tower

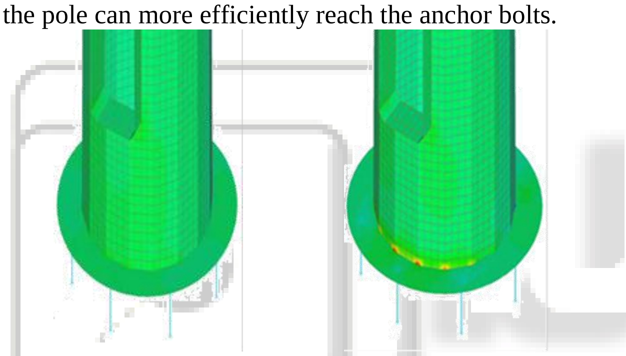
The study described herein was prompted by the collapse of a 140-foot, galvanized, high-mast lighting tower along I-29 near Sioux City on November 12, 2003. At the time of collapse, the winds were reported to be from the northwest at 37 mph and had reached a peak of 56 mph earlier that day the tower fell toward the southeast, as expected with the winds from the northwest (the predominant wind direction in the winter).

Three primary tasks were included in the investigation:

- Task 1: Determine the Cause of the Cracking
- Task 2: Develop a Retrofit Procedure
- Task 3: Assess the Remaining Iowa Towers

Stress analyses and fatigue analyses by the present AASHTO specifications [1] indicate that the towers at both locations could be susceptible to fatigue due to wind-induced vibration. (Note that the towers were not designed to the present (fourth) edition of the Specifications, but rather were designed by the previous edition that did not have adequate fatigue design provisions.) Wind-induced vibration has caused fatigue in many different types of luminaire support structures [2-4] as well as sign and signal supports [3-5]. Therefore, it is concluded that the cause of the fatigue cracking was wind-induced vibration from a combination of vortex shedding and natural wind gusts. The critical fatigue details are the base connection, the anchor rods, and the hand hole. The base connections were particularly susceptible to fatigue because of the very thin 3/16 and 5/16-inch thick shell and the relatively thin baseplate (1.25-1.75 inch). Also, the loose anchor rod nuts contributed to the fatigue cracking. Fortunately, the upper portion of the tower, except for the bottom five feet (roughly), does not have any fatigue-critical details.

By this investigation finite element analysis was carried out which get the result as increasing the base plate thickness also resulted in decreases in the in-plane stresses. This observation is attributed to better load distribution around the perimeter of the pole. As the base plate becomes stiffer, all of the stress due to bending of the pole does not just “come out” of the pole at the corners or bend lines. For in-plane stresses, this can be thought of as a shear lag issue in which all of the stress comes out at stiff corners. These locations are hard spots that tend to stiffen the base plate and restrict its bending. However, with increasing thickness, the base plate becomes less flexible itself and the influence of the hard spots is less pronounced. In other words, the forces in the pole can more efficiently reach the anchor bolts.



3 inch base plate 1 inch base plate

Fig. 2: Comparison of stresses at pole-to-base plate connection for 1 inch and 3 inch base plates

III. CONCEPT

As figure3 and 4 shows the structure of top and bottom portion of pole , The concept of design and analysis of high mast pole is Typically, there are usually some functional equipment on the top of the structure such as a wind-force turbine, a radio wave transmitter, a radar, lamps and lanterns which we have to study.

Fig. 3: Typical light pole top structure

Fig. 4: Typical light base

Generally, HMS is designed a taper; slender; multi-sides for lighting and telecommunication purposes. To meet these specific mounting height requirements, the shaft may consist of more than one section to be assembled on site by means of the "slip on joint”. In the past several years, many accidents and much damage were caused by high wind or wind-induced vibrations in such structures that we have to study.

IV. LITERATURE REVIEW

A. C.W. Chien and J. J. Jang (Taiwan Ocean University): [1]:

This paper gives the contributions of high natural frequency components are obtained by Eigenvalue analysis. The method to check vortex resonance and galloping for higher order modes is also presented. Because of turbulent winds in the atmosphere and characteristics of the irregular bluff bodies of the structures are complicated to deal with, a mathematical model, with interactive wind and structure is still impossible at present. This study includes four parts: (1) a survey of geometric configurations and shape factors; (2) along wind and across-wind response analysis; (3) develops criteria for WRD; (wind resistance design); (4) provides case application for WRD procedures.

B. Mal Thomas and Gary Noyes-Brown: [2]:

This paper describes the investigations that were undertaken, and the recommended modifications that would reduce the stress concentration in the pole mast, and hence extend the pole life. The 28 light poles at the freeway interchange were all of similar construction. figer1shows the typical luminaries arrangement at the top of the light poles, and figure 4 shows a typical light pole base, with significant features being the access opening, the gusset plates, base plate anchor bolts and grout. Inspections carried out by Vic Roads identified cracking in 27 of the 28 high mast light poles at the freeway interchange. All cracking was in the light pole mast, at the tip of the gusset stiffeners. The base plates were not fully grouted; poor grouting has been known to contribute to damages of anchor bolts in other light poles and sign. Bolts need to be checked for stress due to tension and shear, however additional stress due to bending needs to also be considered if the bolts have a free length due to insufficient grout.

C. Counsell Taplin (AASHTO-2006): [3]:

In this paper the American Association of State Highway and Transportation Officials (AASHTO) have commissioned significant research in the USA in the last five years. Culminating in the AASHTO "Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals" (AASHTO 2006) .This standard provides a tool for design of light poles and sign gantries. This research by AASHTO has been undertaken in response to the failure of numerous light poles in the USA. For example, in Iowa in 2003, a 43 meter high light poles collapsed (see in fig.1) prompting an extensive investigation into this type of structure.

V. RESEARCH METHODOLOGY

The research methodology will cover as follow –

- To discusses the main factors that contribute to galvanization-induced cracking at various stages of fabrication including cold working, welding, galvanizing, and material chemistry
- To presents the general framework of the analytical model that was adopted to predict the cracks life of high mast poles with pre-existing cracks at the pole-to-base plate connection detail. The details of the dynamic structural analysis, Static loading analysis, and reliability analysis will be presented.
- To presents the results of the analysis that was conducted on various pole configurations at different locations throughout the state. Calculated results will be presented in detail for a specific pole configuration
- To describes some of the available repair options that can be considered in lieu of replacing damaged poles.

VI. CONCLUSION

The main conclusion will be drawn find out it is possible to reduce all the cracks found at the gusset of solar light pole Also the future scope for developing design model for any profile can be identified.

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