# Study of the Effects of Wind Power

# To Establish Fatigue Design Criteria for High-Mast Poles


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# Abstract

Traffic signal poles and high-mast poles are used by transportation agencies to control and illuminate intersections; their structural design is governed by national specifications. High-mast poles are lights located around highway interchanges that range from 80 to 140 feet in height. Unfortunately, these flexible structures are susceptible to vibration from wind leading to fatigue cracking near the welds. Because of the nature of failure in some areas of the country, recent changes to the requirements have called for expensive member size increases. However, for the areas that in the past had no problems with failures, such increases may be unnecessary and uneconomical.

In a previous study conducted by the University of Wyoming, fatigue cracking of traffic signal poles was determined to be directly related to the average wind speed. Recommendations of changes to the requirements of lower wind areas were made for the traffic signal poles. However, high-mast data did not indicate the same behavior.

The goal of this research is to gain a more complete understanding of the relation between wind speed and high-mast pole cracking through the collection of more data. This research project will further analyze the data collected through a cracked and non-cracked categorization taking into account the natural frequency of the structure and the characteristics of the wind spectrum at the location of interest. It is hypothesized that the cracking is related not to the wind speed, but rather the wind that causes vortices to be shed at frequencies near a resonance. When resonance occurs, the vibrations build upon themselves creating a fatigue failure situation. Through a database that will be created, it will be possible to make further recommendations of the requirements in specific areas and better predict where high-mast poles must be designed to be particularly fatigue resistant.

## Background

Traffic signal poles and high-mast poles are susceptible to vibration from wind, which can lead to fatigue failure. Due to this occurrence in certain areas of the country, recent changes have been made to the Fourth Edition of the AASHTO Luminaire and Traffic Signal Specification (AASHTO, 2001). These changes require an increase in size and, therefore, cost of the structures. In a previous study conducted by the University of Wyoming, data was collected to validate the use of wind power to predict fatigue damage of traffic light signals. Other in-service elements were also tested, such as structure age, length, and diameter. The objective of the study was to provide recommendations of change to the AASHTO requirements. One recommendation made was to require more in-depth inspections of the structures during their first six years of life and then again after 15 years. Another was to create a national database for all cantilever structures so as to continue the collection of data. More importantly was the recommendation that would allow areas with a lower wind speed to be placed in an additional fatigue category that would require more economically sized traffic light poles (Price, 2009). During this study, 700 high-mast luminaires inspection reports were collected along with the traffic-signal pole data. This data did not show the same direct relationship of fatigue to high wind speed. Therefore, the same recommendations could not be made for the high-mast structures to AASHTO as the traffic-signal poles. The goal of this research is to gain a more complete understanding of the relation between wind speed and high-mast pole cracking through the collection of more data.

## Description of Proposed Research

Fatigue cracking in high-mast poles is not caused by dead load or the weight of the structure itself. It is caused by the stress caused by the wind vibrations. The reoccurring difference of these stresses creates a stress range, which causes cracking. The previous study indicated that high wind speeds alone cause enough stress range to fail traffic-light signal poles. However, another factor is present when analyzing high-mast structures. Because of their 80-140 length, high-mast poles possess a natural frequency that can be met by the frequencies in the wind force. It is hypothesized that the cracking is related not to the long-term sustained wind speed, but rather the wind that causes vortices to be shed at frequencies near a resonance. When this resonance occurs, the vibrations build upon themselves or lock-in with each other as seen in Figure 1. This creates larger stress ranges and, therefore, fatigue situations. In order to test this hypothesis, the collection of more data is necessary.

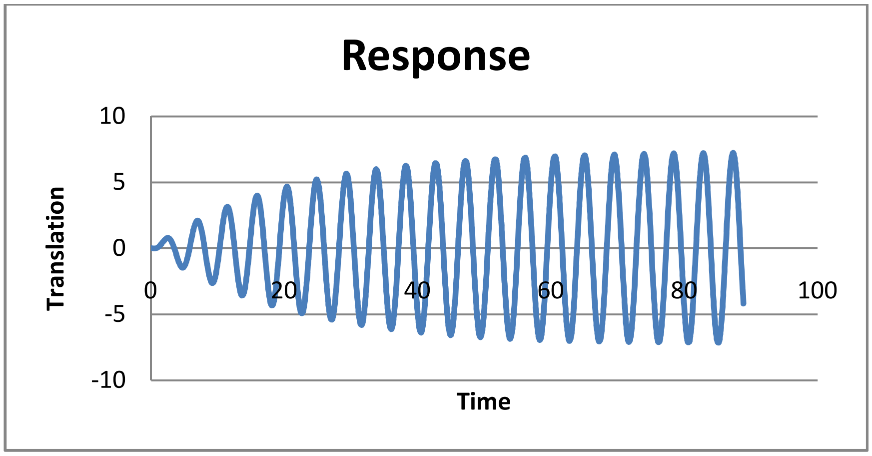


Figure 1

The initial collection of data for this research was a survey sent to 50 state bridge engineers. The survey inquired of their traffic-light signal and high-mast existence, inspection requirements and failures. This data was compared against Wind Power Classification of each area. The Wind Power Classification (WPC) was determined by the *Department of Energy's Wind Program and the National Renewable Energy Lab* (NREL). WPC is a measure of wind power, which is the energy available from wind in a certain location. The factors of WPC include wind velocity and air density. Because air density is considered constant, velocity is the highest contributing factor. The data collected will be compared with the associated WPC.

The high-mast data that is collected will be examined using statistical analysis. In order to model the data in a way that will serve the purpose of the research, it will be put into a binomial logistic regression. The model is binary because there are only two possible outcomes for each high-mast: cracked, or non-cracked. The models created in the previous University of Wyoming study mentioned above created very complex models that require more data. It is one objective of this research to be able to create logistical models. These models will be validated in several different ways.

## Role and Responsibilities

It will be necessary to collect more data involving both the high-mast structures and the WPC in each area. For the high-mast luminaires, I will be both reviewing local information and testing models to interpret their responses to resonant forces. The WPC data must be re-analyzed in a way that corresponds with the given hypothesis. That is, higher attention must be given to the velocity distribution of the wind and the vortices it creates.

I will also be creating a database of all the data collected.  This will assist in predicting where high-mast poles must be designed to be particularly fatigue resistant, therefore, reaching the objective of this research; making further recommendations of the requirements in specific areas.

## Timeline

The anticipated start date for this research is May 10$^{th}$.  There will be a preliminary report requested on September 15$^{th}$.  The expected completion date for this research will be December 31$^{st}$.

## References

AASHTO, A. A. (2001). *Standard specifications for structural supports for highway signs, luminaires, and traffic signals* (Vol. 4th). Washington, District of Columbia: American Association of State Highway and Transportation.

Price, R. P. (2009). *Use Of Wind Power Maps To Establish Fatigue Design Criteria For Cantilever Traffic Signal Structures.* January: Proceedings Annual Transportation Research Board.

## Award Request/Statement of Cost Share

The total amount requested is $5000 for this research. Of this amount, $4800 will go toward the student stipend and $200 will go towards miscellaneous supply costs. There will be no non-salary or travel expenses. None of this research will be covered from other funding sources, nor are other sources available at this time. Dr. Puckett will be spending approximately 2 hours per week working with me which will total to 50 hours.