Kansas Department of Transportation

TECHNICAL SUMMARY

Computational Fluid Dynamics Investigation of High Mast Illumination Poles: Influence of Light Fixtures

Report Number: KS-26-01 ▪ Publication Date: January 2026

Briceson Junge
Caroline Bennett, Ph.D., P.E.
William Collins, Ph.D., P.E.
Jian Li, Ph.D., P.E.
Mark Ewing, Ph.D.

The University of Kansas

Introduction

High Mast Illumination Poles (HMIPs) are lighting towers that are taller than 55 ft (16.8 m) and are typically located along highways and rest stops. In March 2019, a wind event, referred to as a "bomb cyclone," caused several HMIPs in Kansas to excite and experience large-amplitude deflections on the order of several feet called "lock-in" behavior. Lock-in behavior is when the frequency of vibration matches a natural frequency of the structure and excess deformations will be observed. Pole vibrations can be caused by multiple wind actions and wind-structure interactions, including aeroelastic phenomenon like vortex shedding. Following the bomb cyclone event in 2019, the poles were inspected, and cracks were identified around the handhole openings in several of the structures. These poles were taken out of service having only been in service for approximately one year. Their premature failure caused significant concern. New LED luminaires had been implemented with the construction of these poles. The Kansas Department of Transportation (KDOT) sought to learn if selection of LED luminaires (rather than older-style incandescent fixtures) had any influence on the behavior observed during this event.

The objective of this study was to determine the influence of luminaire type on the susceptibility of HMIPs to vortex shedding using a computational fluid dynamics (CFD) modeling approach. Two types of luminaires were considered: LED and incandescent fixtures. The number of light fixtures was varied, along with orientation of the fixtures with respect to wind flow and wind velocity. Time histories of wind force on the lighting assembly projection were used to determine dominant frequencies produced by the wind flow and were compared with the first three natural frequency modes of poles commonly used in Kansas. This approach can provide insights for wind behavior as it flows across the assemblies, and which, if any, structural modes it may excite. This approach isolates the lighting assembly; therefore, it does not provide insight as to how the lighting assembly and pole respond together.

Project Description

The modeling approach adopted in this research was focused on characterizing wind flow past the lighting assembly, specifically comparing different light fixture types, number of fixtures, orientations with respect to the wind, and wind speed. A two-dimensional CFD modeling approach for the lighting assemblies was selected, reducing computational demands in comparison with those required by a three-dimensional analysis. Therefore, this approach considers a geometrically projected section through the luminaires that neglects small geometric details.

Pressure data was extracted from the models at points on or near the surface on the leeward side of the body in the CFD model. Similarly, the total force components on the surface of the body could be extracted. A time history of these force components was used for analysis to characterize how interactions in the wind with the body create forces acting on the body. Further, this data was analyzed to examine the frequency of oscillation of these forces. These data can be analyzed considering features such as magnitude of force or pressure, as well as through power spectral density (PSD) analysis. PSD curves reveal the dominant frequencies that the time-history record exhibits, which is a useful feature because the frequencies identified in each dataset could then be compared to the natural frequencies of a given HMIP to judge its likelihood of experiencing vortex induced vibrations (VIV).

Project Results

The study has led to the following conclusions: There was no clear indication that LED luminaires might incite a greater response than incandescent luminaires in the first mode. This finding is in contrast to a hypothesis that arose after observations of high-amplitude deformations observed in the wind event of February 2019, which appeared to largely affect structures with LED fixtures. A greater number of Mode 1 hits were observed in models with incandescent luminaires than for LED luminaires when the ±10% natural frequency bandwidth was based on the Mode 2 natural frequency. This finding indicates that incandescent fixtures are more likely to correspond with a Mode 1 response. The number of hits in any frequency range generally increased with wind speed, indicating greater potential for lock-in behavior under vortex shedding with increasing wind speed. Cases in which the wind direction was straight on (0-degree angle with the fixture) corresponded with more frequency range hits than the other wind directions for the three and four fixture configurations. Overall, the results were found to be dependent on wind direction.

The results showed susceptibility of both light fixture types to vortex shedding lock-in behavior across the first three natural modes. There was no identifiable trend that selecting one luminaire type over another could decrease susceptibility to lock-in behavior.

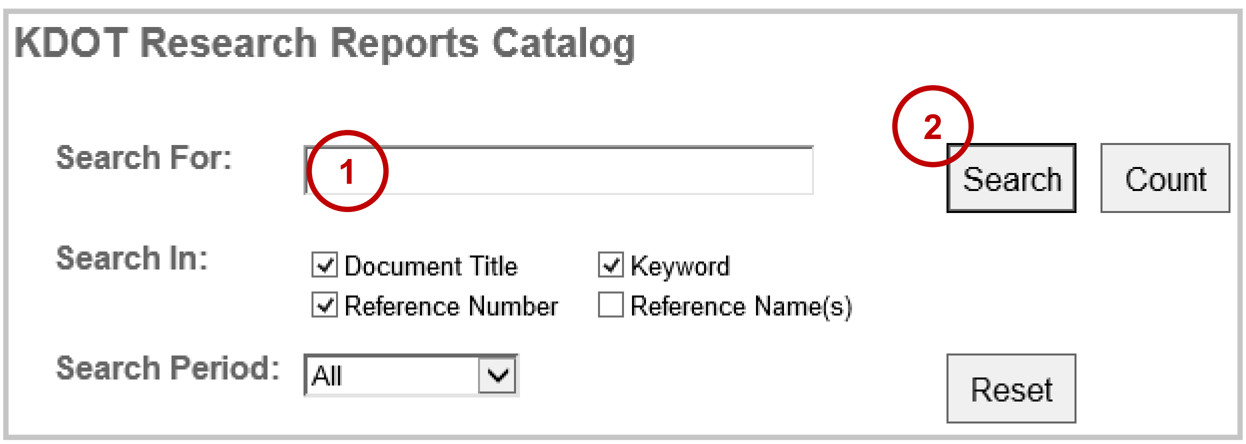
Project Information

For information on this report, please contact Caroline Bennett, Ph.D., P.E., University of Kansas, 1530 W 15th St, Lawrence, KS 66045; 785-864-3235; crb@ku.edu.

Directions for Downloading the Full Report

To download the full report, visit https://kdotapp.ksdot.org/kdotlib/kdotlib2.aspx and do the following:

1. Enter K-TRAN: KS-26-01 in the search box.
2. Click the Search button to the right of the search box.
3. You may have to scroll to find the specific report.
4. To download the report, click on the title of the report to open the PDF file and save it to your hard drive.



If you have any questions, please email us at KDOT.Research.Library@ks.gov.