Wind-Induced Vibration and the Effects on Steel and Aluminum Light Poles

DWM Holdings, January 2016

Executive Summary

Light poles are designed to move, be flexible, and withstand vibration to an extent. Understanding the environmental factor that is wind-induced vibration when installing or maintaining light poles is an everyday reality that must be taken into account, saving money and time.

Wind-induced vibration can have damaging effects on both steel and aluminum light poles. Wind is the natural movement of air here on Earth and is unavoidable. Merriam-Webster defines vibration as “a periodic motion of the particles of an elastic body or medium in alternately opposite directions from the position of equilibrium when that equilibrium has been disturbed.”[1]

This paper explores how wind-induced vibration can affect the performance and strength of steel and aluminum light poles, how Aeolian vibration can be identified, and ways the effects of this vibration can be mitigated — both proactively and retroactively.

[1]“vibration.” Merriam-Webster.com. Merriam-Webster, 2015. http://www.merriam-webster.com/dictionary/vibration. (17 November 2015)

Types of Vibration

There are two common types of vibration: first-mode and second-mode. First-mode vibration is caused by sudden, high-velocity gusts of wind, in which the maximum deflection occurs at the top of the pole. This can be viewed by swaying at the top of the pole. The effects of first-mode vibration are not usually harmful to the light pole because the pole is designed to move, be flexible, and withstand first-mode vibration. See Figure 1.

Second-mode vibration, also known as Aeolian vibration, is caused by low-velocity, high-frequency, steady winds, normally ranging from 5-35mph and giving rise to frequencies of 2-20 Hz. This vibration is believed to be predominantly caused by vortices that form on the back side of the structure as this steady stream of air passes across the pole. The vortices alternate from the top and bottom surfaces and create alternating pressures that tend to produce movement at right angles to the direction of the air flow. This causes a high-frequency, short-cycle harmonic reaction, creating extreme stresses to the middle of the light pole. Humming is an audible signal that Aeolian vibration may be occurring. See Figure 2.

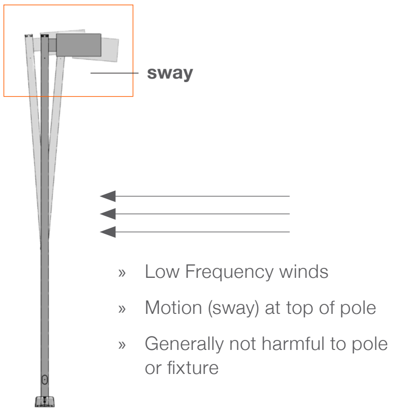


Figure 1

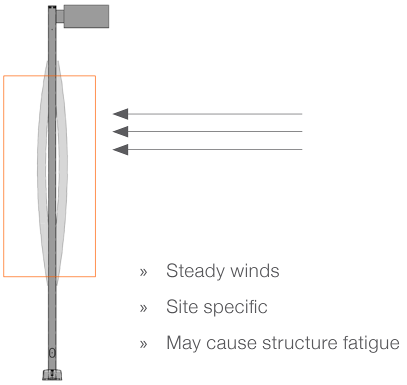


Figure 2

Damaging Effects

The Aeolian vibration phenomenon is site specific and is, unfortunately, unpredictable as to when it may occur. Stress fractures, reduced performance of the pole that can include luminary failure and increased swaying, and knock-downs are all examples of the damaging effects vibration may have on steel and aluminum light poles.

EPA and Wind Load

During pole selection and installation, effective projected area (EPA) should be obtained and wind load should be determined. Light poles are designed to account for the effects of wind. However, EPA and the historical geographic area data should also be evaluated prior to selecting a pole(s) and installation. The area of the pole that is loaded by the wind is EPA; this information can be found by reviewing the pole manufacturer's cutsheet. EPA of the pole must be obtained to ensure the pole selected can support the wind load, depending on the wind zone. It is important to adhere to the guidelines set forth by the American Association of State Highway and Transportation Officials (AASHTO) for wind load. AASHTO has provided the 1994 Fastest Mile Wind Map (see Figure 3) and the 2001 3-Second Gust Wind Map. These standards and codes have been created from historical analysis and research.

UNITED LIGHTING STANDARDS
A DWM COMPANY

United Lighting Standards Provides Quick Response to Vibration Issue

In the Spring of 2014, a community college in the Southeast U.S. had 37 round straight aluminum light poles installed in an open parking lot. The light poles were manufactured by United Lighting Standards (ULS), a DWM Holdings company. While Aeolian Vibration rarely, if ever, occurs in this geographic location, it did eventually take place and resulted in one of the light poles falling down.

Pictures and videos were promptly taken and reviewed by site engineers to determine that it was indeed Aeolian vibration that had caused the pole to go down. Ryan MacVoy, CEO of ULS, reviewed all the video and photos as well and came to the same conclusion. For ULS, a quick response was paramount.

Emery Sheffield of Lighting Partnership — the manufacturer sales representative agency that sold the poles — states, "The company really stands behind their products. Ryan flew down immediately to inspect the site in person and readily had a solution to remedy the situation."

All remaining 36 poles were tested to ensure their safety and all tests came back with positive results. As a precaution, vibration dampeners were installed in the field on all 36 remaining poles. The pole that had initially fallen down was replaced with a brand new light pole fitted with a vibration dampener. Sheffield concludes that he is "very pleased with the way ULS responded."

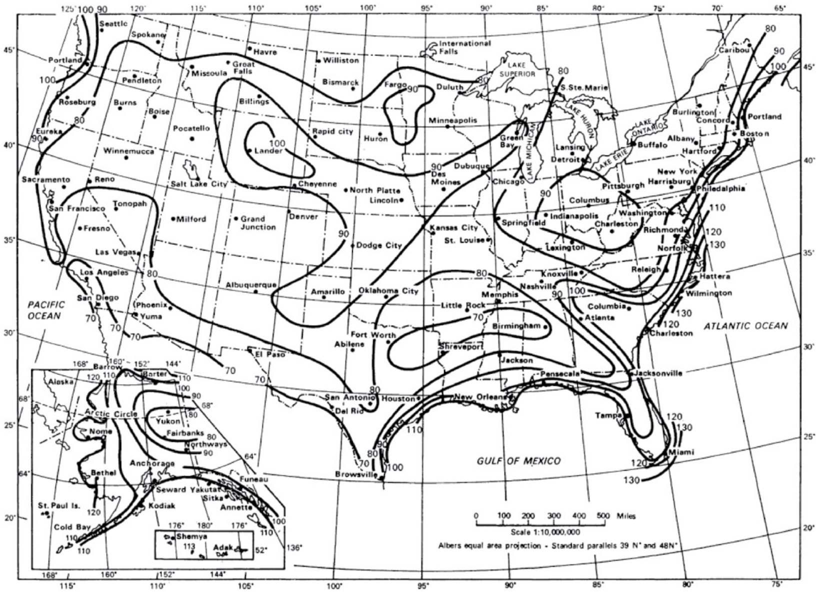


Figure 3

Treatments

Structurally, there are treatments that can be implemented to assist in avoiding or mitigating the negative effects of vibration.

Dr. John Tartaglia, Engineering Manager & Senior Metallurgical Engineer at Element Materials Technology, advises that there are ways to help mitigate metal fatigue before vibration occurs after installation. Incorporating notches and any sharp angles into the design of a pole are poor choices as they will eventually lead to fatigue cracks. During manufacturing and installation, scratches, dings, or stress concentrations made to the surface of a pole — anything that makes it no longer smooth — greatly diminish the strength properties. As for metallurgy, processing materials extensively away from their natural state can cause premature cracks. The heat-affected zone on a pole is, the area of base material which is not melted and has had its microstructure and properties altered by welding or heat intensive cutting operations. The heat from the welding process and subsequent re-cooling causes this change from the weld interface to the termination of the sensitizing temperature in the base metal.[2] Because of the process the metal goes through, the heat affected zone above the weld-line is the most susceptible area for damage on a pole.

For first-mode vibration, simply obtaining EPA, adhering to the AASHTO wind maps, guidelines and standards, as well as any local building codes, should accurately allow for the consideration of first-mode vibration's negative effects.

For Aeolian vibration, there are many factors to take into consideration. First is geographic location. Ryan MacVoy, CEO of DWM Holdings, states, "Overall, Aeolian vibration is most prevalent in wide-open, typically flat spaces where there are few to no buildings, trees, or other barriers to stop the wind. Examples include farm land, airports, open sporting fields, and under-developed areas." Second, consider the material and shape of the pole. MacVoy says, "The most susceptible for Aeolian vibration is the straight square aluminum pole because it has corners and a flat surface. The least susceptible is the round tapered steel pole. The round shape allows wind to more easily pass around the pole." Dr. Tartaglia states that a "combination of materials, i.e., steel and aluminum together, typically equates to more fatigue. It is best to select either only steel or only aluminum material."

Many may be curious if anchor-based poles are more susceptible to Aeolian vibration than embedded (or direct-burial) poles. MacVoy has found that there is little to no difference as long as the poles are installed correctly, with the correct back-fill.

When it is suspected or detected that Aeolian vibration could occur, or is occurring, in a certain geographic area, a dampening system can be used to minimize the stress effects. A dampening system disturbs Aeolian vibrations by transferring the vibration movement away from the pole and into the dampener. To determine if such a system is needed up front and needs to be installed by the pole manufacturer, it is best to base the decision on the past history of an area using wind maps and the recommendation of the local site engineer and/or architect. These systems can also be field-installed by an electrical contractor.

There are specific signs that determine if Aeolian vibration has occurred. Dr. Tartaglia states, “It is hard for a layman to always determine persistent slip bands because you need a microscope, but it is a great way to determine early on if fatigue is setting in.” Other signs in the field include fatigue cracks and corrosion; cracked lamps; movement that travels down the pole shaft and pole damage is visible, or an audible humming sound.

Recommended Inspection and Maintenance

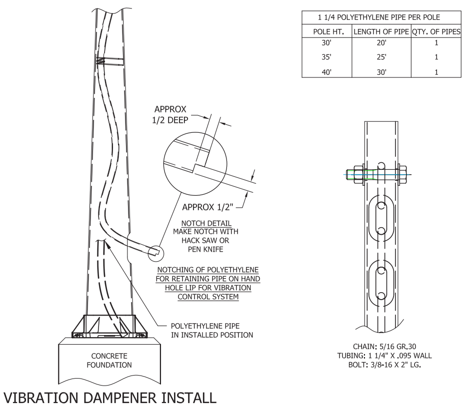
In the field, the best way to help mitigate the negative effects of vibration is to perform frequent inspections. Both MacVoy and Tartalgia agree that, at a minimum, annual inspections should be conducted and all findings should be thoroughly documented. Tartaglia says, “The more frequest inspections that can be conducted, the better ... and be sure to thoroughly document what is found with the date referenced.”

To properly conduct a thorough inspection, the inspector should be close enough to touch the pole; a ladder or bucket truck will be required. Start the inspection at the base of the pole and move up to the top. At the base, anchor bolts and leveling nuts should all be accounted for and properly secured. Missing hardware is a sign of improper installation and loose hardware can cause additional movement on the pole, which should always be avoided. The hand hole cover should be removed and the cover and all fittings thoroughly inspected. Along the pole shaft, the area above and below the weld line, the most susceptible area, should be closely inspected for fatigue cracks, dents, and damaged coating. In addition, any rust on steel and corrosion on aluminum should be noted. At the top of the pole, hardware should also be accounted for and properly secured. See examples below.


Corrosion at the base of a pole.


Rust and corrosion inside of a pole.

If Aeolian vibration is suspected, it is recommended to take next steps to remedy the situation as quickly as possible. Early detection of this problem provides a greater solution base. Solutions include: change the location of the light pole; modify the landscaping to alter the wind pattern; reinstall with a different shaped pole — from straight to round, for example; heat-treat the pole to bring it back to an approved level; or — the number-one and least-expensive option — install a vibration dampener.



1 1/4 POLYETHYLENE PIPE PER POLE		
POLE HT.	LENGTH OF PIPE	QTY. OF PIPES
30'	20'	1
35'	25'	1
40'	30'	1

Vibration dampner drawing and specifications.


View of vibration dampner inside an aluminum light pole.

Vibration dampeners are offered by pole manufacturers as a vibration mitigation option. DWM Holdings brand companies' vibration dampening system consists of a length of chain encased in a plastic tube that runs approximately two-thirds the length of the pole. This piece disturbs the harmonic cycling of the shaft (Aeolian vibrations) by touching the inside surface of the pole in a random and spiral manner. While the dampener does mitigate the stress effects of the vibration, it is not a guaranteed solve for such an occurrence.

To learn more, visit www.dwmholdings.com or call 586-541-0013.

[2]“Heat-affected zone.” Wikipedia.org. https://en.wikipedia.org/wiki/Heat-affected_zone. (20 November 2015)

Bios

Ryan MacVoy is Chief Executive Officer of DWM Holdings, parent company of a portfolio of lighting standard manufacturing companies, which include: United Lighting Standards; General Structures, Inc.; Lyte Poles; and UniPost Systems.

Emery Sheffield is the Montgomery Branch Manager for Lighting Partnership, based in Birmingham, Alabama. Lighting Partnership is a manufacturer sales representative partner for United Lighting Standards, a DWM Holdings company.

Dr. John Tartaglia holds B.S. and Ph.D. degrees in Materials Engineering from Rensselaer Polytechnic Institute in Troy, New York, and is an expert in die and other wrought steels, aluminum, magnesium, fatigue, failure analysis, scanning and transmission electron microscopy, and energy dispersive spectroscopy. He is an experienced expert witness in failure analysis litigation and has given numerous seminars and training classes on metals testing and analyses. Dr. Tartaglia was recently elected as a Fellow of ASM International. Dr. Tartaglia is Engineering Manager and Senior Metallurgical Engineer at Element Materials Technology in Wixom, Michigan.

Additional Resources

Devi, Suma, Govindaraju, L (May 2014), "A Study on Wind Induced Vibration on Lighting Poles," IJRET: International Journal of Research in Engineering and Technology, Volume: 03 Special Issue: 06.

Jones, Wes, Manis, Peter (2008), "Wind-Induced Harmonic Resonance: Considerations for Light Pole Design," TECHBriefs 2008 No. 3.

Warranty/Disclaimer

The statements made herein do not constitute an offer. They are based on the mentioned assumptions and are expressed in good faith. Where the supporting grounds for these statements are not shown, DWM Holdings will be pleased to explain the basis thereof.

DWM Holdings warrants that the products manufactured and delivered under all of its brand companies are free of substantial defects in material and workmanship for the period of the warranty attached to each product. All products are designed and fabricated to withstand the load applied when properly selected using the EPA charts provided or through guidance from the manufacturer. Some geographical areas have special wind conditions that can create wind-induced vibrations causing a fatigue problem. No method has yet been found for accurately predicting destructive lighting pole vibration. These conditions are unique but cannot be guaranteed against and are the responsibility of a local site engineer. As a result, DWM Holdings expressly disclaims any warranties (express or implied, oral or written) with respect to damage caused to the products or caused by the products as the result of wind-induced vibrations. DWM Holdings is not liable for any repairs, replacements, or adjustments to the products or any costs of labor performed by a customer or others without DWM Holdings' prior written approval.