



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

DWM Holdings, January 2016

## Executive Summary

Vibration is defined 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.”<sup>1</sup>

Among the types of vibration that effect steel and aluminum light poles, wind-induced vibration is particularly detrimental. Although light poles are designed to respond dynamically to the phenomenon, under the right conditions, wind vibration can drive even the most soundly designed structures to fail.

This paper explores how wind-induced vibration can affect the performance and strength of steel and aluminum light poles. Stress fractures, reduced performance of the pole that can include luminaire failure and increased swaying, and knock-downs are all examples of the damaging effects vibration may have on steel and aluminum light poles. The paper then goes on to discuss what Aeolian vibration is, how it can be identified, and ways the effects of this vibration can be mitigated — both proactively and retroactively.

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<sup>1</sup>“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. This results in a maximum deflection near the top of the pole that manifests visually as the pole appearing to “sway” in the wind. The effects of first-mode vibration are not usually harmful, as light poles are designed to move and flex to withstand first-mode vibration. See Figure 1 below.

Second-mode vibration, also known as Aeolian vibration, is caused by low-velocity, high-frequency, steady winds ranging from 5 to 35mph and giving rise to frequencies of 2-20 Hz. This vibration is 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 originate from opposite sides of the structure and create alternating pressures that produce movement at right angles to the direction of the air flow. This causes a high-frequency, short-cycle harmonic reaction, resulting in stress concentrations around the pole’s midsection. See Figure 2 below. While first-mode vibration is often visible in the form of swaying at the top of the pole, second-mode vibration is most often heard by an audible humming noise coming from the pole.

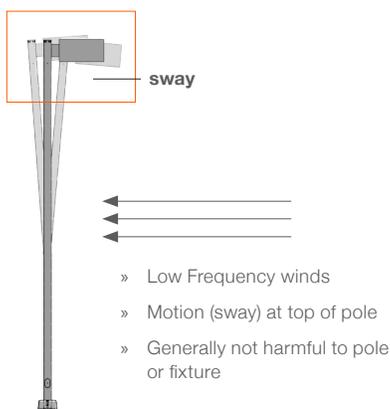


Figure 1

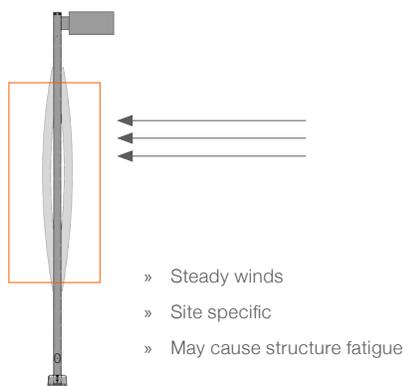


Figure 2

In addition to humming, there are other cues that signal a structure may have experienced Aeolian vibration. Dr. John Tartaglia, Engineering Manager & Senior Metallurgical Engineer at Element Materials Technology 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, resulting in visible pole damage; or an audible humming sound.

## Determining when Aeolian Vibration Might Occur

To date, there are no documented methods of predicting the occurrence of Aeolian Vibration. However, certain conditions are known to increase the likelihood that it might take place. 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.”

Vibration sets into the weakest point of a pole. For anchor-based poles, the heat-affected zone (HAZ)<sup>2</sup> directly above and below the weld line on anchor-based poles creates this weak point. Due to this, readers may be curious if anchor-based poles are more

## DWM Holdings 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 one of DWM Holdings’ brand companies. 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 DWM Holdings, also reviewed all the video and photos and came to the same conclusion. For DWM, a quick response was paramount.

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.

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 ... [I was] very pleased with the way [they] responded.”

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

susceptible to Aeolian vibration than embedded (or direct-burial) poles. According to MacVoy, there is generally little to no difference as long as the poles are installed correctly, with the correct back-fill. If Aeolian vibration occurs, it will find the weakest point of any pole — eventually causing it to fail.

## Avoiding and Mitigating the Effect of Aeolian Vibration

There are several ways to prevent Aeolian Vibration from taking place, or to mitigate its effects after it has occurred.

### Pole Design and Selection

Of the options to address Aeolian vibration, the most proactive is ensuring that the pole is sufficiently designed for the maximum wind load it might experience. Wind load can be thought of as the effective projective area (EPA) of what the pole will support in combination with the maximum wind speed that the pole will experience. The maximum wind speed is largely a function of geography, and is typically based on historical data.

It is important to adhere to the guidelines set forth by the American Association of State Highway and Transportation Officials (AASHTO) when determining wind load. AASHTO has provided the 1994 Fastest Mile Wind Map (see Figure 3) and the 2001/2009/2013 3-Second Gust Wind Maps. These standards and codes have been created from historical analysis and research.

Once the EPA and wind speed are known, manufacturers' cutsheets can be used to determine the pole best suited for a given application.

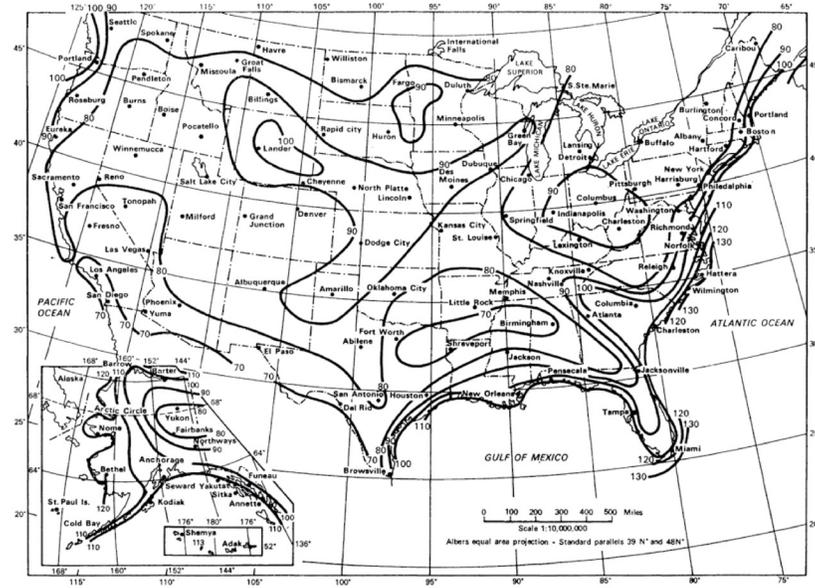


Figure 3: AASHTO's 1994 Fastest Wind Mile Map

### 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 Tartaglia agree that, at a minimum, annual inspections should be conducted and all findings should be thoroughly documented. Tartaglia says, "The more frequent inspections can be conducted, the better ... and be sure to thoroughly document what is found with the date referenced."

To properly conduct an inspection, the inspector should be close enough to touch the pole. This may require the use of a bucket truck, ladder, or lift.

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 HAZ), should be closely inspected for fatigue cracks, dents, and coating damage. Additionally, any rust on steel and corrosion on aluminum (see examples on next page) should be noted. At the top of the pole, hardware should be checked for tightness and properly secured. Any missing hardware should be replaced immediately.



Corrosion at the base of a pole.

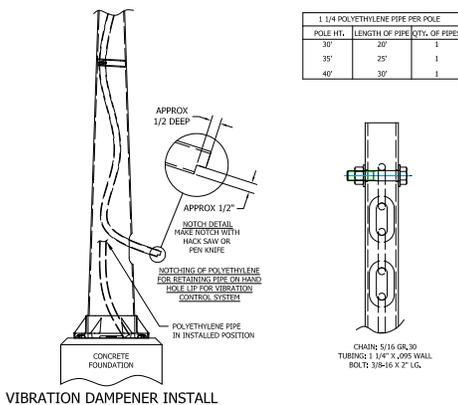


Rust and corrosion inside of a pole.

### Install a Vibration Dampener

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 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.

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 solution.



VIBRATION DAMPENER INSTALL

Vibration dampner drawing and specifications.



View of vibration dampner inside an aluminum light pole.

To learn more, visit [www.dwmholdings.com](http://www.dwmholdings.com) or call 586-541-0013.

## 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.

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