

As an industry leader in light pole design and manufacturing, Hubbell is committed to providing information to help designers avoid wind induced pole vibration. This paper presents a practical guide for recognizing and minimizing the potential damaging effects of wind on light poles.

Defining Wind-Induced Vibration

Wind induced pole vibration is partially defined, or characterized, by the type of movement observed in a pole system.

Two common types of pole vibration are:

FIRST MODE (Harmonic) VIBRATION



SECOND MODE (Resonance) VIBRATION



Figure 1: First and Second Mode Pole Vibration

FIRST MODE VIBRATION is characterized by a side to side movement that has a maximum displacement at the top of the pole. This behavior may be referred to as “sway”. The frequency of movement is about 1 cycle per second or less. Because the vibration frequency is comparatively small, the onset of material fatigue will take longer than poles exhibiting higher modes of vibration.

SECOND MODE VIBRATION is characterized by a symmetric oscillation at or near the midpoint of the pole shaft. The oscillation frequency typically ranges from 3-6 cycles per second. Second mode vibration occurs when air moving across a pole reaches “lock-in” velocity. At “lock-in” velocity, Vortex Shedding produces alternating transverse forces that oscillate the pole at one of its natural frequencies. The onset of fatigue cracking or structural failure may occur quickly under such conditions.

VORTEX SHEDDING is the phenomenon caused by a steady, constant velocity wind moving across a slender, flexible object, like a pole. Vortices forming on the sides of the pole create localized, pockets of low pressure. These pockets alternate, creating alternating forces that act on the pole perpendicular to the wind direction.

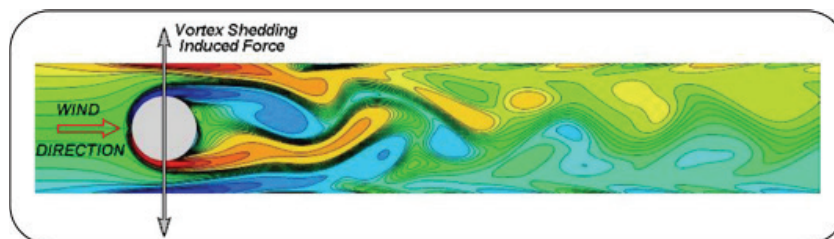


Figure 2: Vortex Shedding simulation about a cylinder demonstrating alternating low pressure zones in wake

EFFECTS OF WIND INDUCED VIBRATION

The effects of wind induced vibration will vary as they are influenced by many factors; including site features, pole design and shape, and wind conditions. Wind induced vibration can lead to reduced performance in the pole systems and may result in structural failure.

Environmental Conditions that Increase Risk

Environmental variables like wind conditions, terrain, landscape, and site structures greatly influence how wind will affect pole systems. This partial list includes application attributes that may facilitate wind induced pole vibration.



Fig. 3

Regional Geography – Expansive, flat areas with little natural or man-made wind breaks as common in the upper mid-west, plains states, and some coastal regions.

Figure 3: Coastal Locations



Fig. 4

Flat, Open Terrain – Localized flat areas with little or no wind breaks (i.e. large parking lots, large fields, top of parking structures, causeways)

Figure 4: Open terrain examples in central US



Fig. 5

Mountains, Foothills, Cityscapes – Areas with steady air currents or areas with natural or man-made features that alter wind patterns

Figure 5: Illustration of wind pattern changes caused by structures



Fig. 6

Airports – Turbulent air from aircraft and localized flat areas absent of objects to break the wind currents

Figure 6: Jet blast



Fig. 7

Bridges and Parking Decks – Flat, elevated structures in open areas can also transfer vibration generated by moving vehicles or move on their own as a result for vortex shedding about its structural supports

Figure 7: Example of parking deck with pole mounted luminaires.



Fig. 8

Local Conditions - Site specific terrain and conditions

Figure 8: Unique application.

Design Factors To Consider

Pole selection can also contribute to the potential for wind induced vibration. Relevant design attributes are:

Loading – Luminaire size (EPA), luminaire weight, luminaire quantity, and luminaire orientation will influence the behavior of the pole and its susceptibility to vibration. Loads that exceed the design limits of the pole may result in structural failure. Also problematic, very small loads and zero loaded poles (lightly damped) may be prone to vibration.

Height – Pole height governs the amount of deflection a pole will move and the size of the moment generated at the pole base. An increase in height will increase both values, making it more susceptible to wind induced vibration.

Wall Thickness – Pole wall thickness affects the rigidity of the pole. Increasing the wall thickness will reduce its flexibility and reduce the effects wind has on the system.

Material – Common pole materials include steel, aluminum, concrete, fiberglass, cast iron and wood. Material properties vary between material types. Steel and aluminum are very common materials used in light pole manufacturing. Of the two types, steel has higher strength of material properties than aluminum.

Shape – Pole shape (cross section geometry) also influences pole performance because aerodynamic characteristics change by shape. When comparing square poles to round poles, square poles have higher drag coefficients. Square poles may also have more complex, asymmetric flow patterns around the pole. This is especially true for winds approaching off angle from the either the flat surfaces or corners.

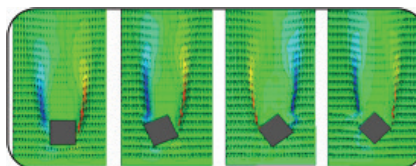


Figure 9: Simulated flow about a straight square cylinder at various wind approach angles

Taper – Taper can also change the aerodynamic characteristics of the pole, shifting the critical wind velocity that causes Second Mode vibration.

Recommendations

Evaluate risk - Inspect site conditions and evaluate the risk of problematic wind conditions.

Mitigate risk through pole selection -

- Avoid poor damping conditions caused by under loading poles. Poles should not be installed without the luminaires they are designed to support.
- Strengthen or stiffen the pole via material selection (i.e. choose steel over aluminum), increase wall thickness, increase the cross sectional size, and/or minimize height.
- Consider round tapered poles.

Increase Damping - The uses of factory or field installable damping devices offer an economical option for minimizing destructive vibration. Most dampers reduce the amplitude of mechanical vibrations by adding mass that moves at a different rate than the shaft of the pole. Some dampers also change the natural frequency of the pole by moving the excitation frequency, thereby changing the critical velocity and the forces generated by vortex shedding.

First Mode Dampers

First Mode vibration dampers are designed to reduce the amplitude of pole top deflection caused by First Mode vibration.

Hubbell offers a First Mode vibration damper (Q41) that is factory assembled, painted to match, and ready for field install. It is designed for 4", 5", and 6" square aluminum and steel lighting poles.



Figure 10: First Mode Vibration Damper (Q41)

Recommendations Ctd...

Second Mode Dampers

Second Mode vibration dampers are designed to alter the natural frequency at which the pole will resonate, reducing the pole movement and the onset of material fatigue caused by wind. Both field installable and factory installed Second Mode vibration dampers are available.

Hubbell offers two types of Second Mode vibration dampers.



Figure 11: Canister and tube dampers

Serpentine Tube (special order) vibration dampers are field installed through hand holes. These devices wrap around the inner surface of the pole shaft, are free standing, and reduce motion.

Interior Canister (Q42) vibration dampers feature an internal cylinder that houses a cushioned, weighted rod pendulum. This device moves in the opposite direction of the shaft, disrupting vibrations. The impact of the pendulum against the cylindrical housing may be audible under certain conditions. This type of damper is factory installed.

Perform and Record Pole Maintenance

An important tool to reduce risk and the effects of wind induced vibration is a properly implemented pole maintenance plan. Inspections should be conducted on a routine basis, starting at the time of installation, week 1, month 1, month 6, and then annually thereafter. It is also advisable to check installations for changing pole movements, damage, or signs of stress after a major wind event or changes to the site that may affect wind patterns. Site changes may include new building structures, new landscape plantings, or growth of existing landscaping. Inspecting for the effects of vibration is a very important part of any proper maintenance plan. If any effect exists, the pole can be compromised in a short period of time. The results can be as severe as structural failure. Signs of vibration can be observed following this basic guideline, special training or certification is usually not required.

- Observe pole movement during windy conditions. Excessive deflection, rapid oscillation at the shaft midpoint, or audible thumping of electrical conductors in the pole may be indications of pole vibration.
- Low torque values on anchor bolts.
- Loose or missing parts at the luminaire and/or pole top are an early indication that the pole may be vibrating in application. Missing pole caps, loose HID sockets, and prematurely failing HID lamps are a few examples. Correct or replace as necessary.
- Look for signs of rust and corrosion above the pole base plate weld and about the hand hole. Corrosion may indicate an area of fatigue. If present, remove the corrosion and wipe clean. Hairline cracks just above the pole base plate weld may indicate shaft material fatigue. An inexpensive die may be used to aid in detection.



Figure 12: Example of fatigue cracking at the base plate weld

- For square poles, inspect the corners near the base plate in a similar manner.
- Review the entire pole shaft for signs of finish deterioration.

If any indications of fatigue exist, a qualified and experienced structural engineer should be consulted, the affected pole should be taken down immediately, and an inspection should be performed for the entire site. If vibration has or is occurring, but the pole is deemed to be structurally sound, mitigation steps should be taken immediately by adding dampers and monitoring the pole behavior. If vibration continues after dampers are added, an alternate pole shape or construction should be considered.

Pole Warranty

Wind induced vibration is a naturally occurring phenomena that may lead to structural failure of poles. Such a failure is not an indication of inferior design, material, or craftsmanship. As such, Hubbell's warranty does not apply to and Hubbell shall have no liability for any failure of the products or damage due to fatigue failure or similar phenomena resulting from induced vibrations, harmonic oscillation or resonance associated with movement of air currents around the product.