

Light Poles: A Guide to their selection, installation and maintenance, including the cause and effects of pole vibration

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Light poles are structures designed to support single or multiple luminaire configurations. First and foremost a light pole is an engineered structure—sufficiently strong to withstand the physical forces of the application, capable of providing a long, relatively maintenance-free service life and pleasing in appearance. Their primary function is to resist the combinations of luminaire weight, ice and wind forces which poles may encounter over their expected life. Along with the foundation system, the primary force a pole must withstand is from wind. The variety of pole shapes, heights, sizes and quantity of luminaires to be supported necessitate the completion of an engineering analysis to ensure suitable strength to safely accommodate various loads. Due to unforeseen loadings and wind events which may occur, it is advisable to select a pole with ample capacity.

Factors Affecting Pole Selection

Common materials used to construct poles include steel, aluminum and fiberglass, with steel being the most common due to its strength and affordability. In some cases concrete, cast iron and wood may also be used. While the most common pole shapes are round or square in cross-section, fluted and other ornamental cross-sections are also available. Once the designer or owner has selected the pole style and material, the following factors must be identified to properly design a pole fixture system capable of withstanding its application and environment (*see page 11 for data worksheet for pole selection*).

- **Mounting Height [MH]:** Determine the fixture mounting height. This is the distance at which the luminaire is mounted above the base of the pole shaft. When poles are mounted above grade (*for example, locations on top of parking decks or on a bridge*) the height above grade must also be determined. The height above grade is the distance from the pole base to the surrounding terrain. The height above grade is important since the wind velocity increases with elevation. When poles are mounted above grade, contact the factory for assistance.
- **Luminaire Selection and Configuration:** Once the luminaire is selected note the fixture catalog logic, EPA, weight, and the distance from the center-line of the pole to the center of the luminaire. When used, the weight and EPA ratings of mounting brackets and arms must be included as well. EPA values are not additive—for example, the EPA for 4 @ 90° is not 4 times the EPA of a single luminaire. The EPA values for Cooper Lighting luminaire mounting configurations are noted on pole specification sheets and in the Invue and the McGraw-Edison pole sections of the Buyer's Guide.
- **Auxiliary Equipment and Special Loading:** Frequently, besides general purpose area lighting, poles need to support special task lighting, such as building and sign illumination, or auxiliary equipment, such as cameras, banners, signs, pennants, speakers, or holiday decorations. EPA, weight, quantity and mounting height of the auxiliary equipment must be provided to the factory to be included in the loading calculations. If signs, banners, pennants or holiday decorations are to be installed on a pole, area, size, weight and location must be noted. Pole-to-pole banners are not recommended without a special engineering analysis. Consult the factory.

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- **Wind Speed [MPH]:** It is critical that the proper wind speed be determined for the installation site. To aid in the determination of an application wind speed, Cooper Lighting publishes a 50 year mean recurrence iso-tach wind map. When a job site is located near or between two wind zones, the higher value must be used. This map is based on the 1994 AASHTO code requirements and is intended as a general guideline only. Local engineering standards should be consulted to determine the exact wind loading conditions for your application.
- **Terrain and Special Wind Regions:** Flat and open terrain may cause wind induced pole vibrations that may require special attention (*see page 5 for more information regarding the effects of pole vibration*). In areas such as foothills or mountain passes, where hills and local topography may create a funnel affect, wind speed values may need to be increased above the values shown on the wind map. Other potential applications which may require special considerations include, but are not limited to, parking structures, bridges, areas on or adjacent to airports or wind farms, and areas that are subject to low steady state winds such as open plains. Additionally, there are Special Wind Regions identified by American Society of Civil Engineers (ASCE). These areas include mountainous regions and certain coastlines requiring more specific wind information to select an appropriate wind speed.
- **Finish:** Generally polyester powder coat paint finishes are excellent for most environments due to their endurance and excellent color retention. However, consideration should be given to job sites near coastal areas (*i.e. salt water corrosion*) or those with corrosive conditions such as sewage treatment plants. These conditions may require special finishes and coatings. Check with your Cooper Lighting customer service representative or the McGraw-Edison Architectural Colors Brochure for standard finish offerings.
- **Special Requirements and Mounting Configurations:** For special engineering codes, breakaway requirements, T-Bases, bridge mounting locations, consult the factory.

Pole Selection Examples (*see page 11 for data worksheet for pole selection*)

Example 1

Job Name	Forest Mall
Agent	AAA Lighting
Job Location	Raleigh, NC
Wind Speed (Use Iso-tach Wind Map—50 yr.)	90 mph (Near or between zones, use highest)
Luminaire Catalog Logic	Credenza Large [ZDL]
Quantity / Orientation	2 @ 180°
Pole Height	30 ft.
Luminaire Mounting Height (MH)	30 ft.
Pole Catalog Logic	Square Straight Steel [SSS]
Luminaire and Arm EPA	4.72 sq. ft. including arms
Bracketry EPA	--
Total EPA	4.72 sq. ft.
Luminaire and Arm Weight	128 lbs.
Bracketry Weight	--
Total Weight	128 lbs.

Mtg. Height (Ft.)	Catalog Number	Wall Thickness (Ga.)	Base Square (In.)	Bolt Circle Dia. (In.)	Bolt Proj. (In.)	Shaft Size (In.)	Anchor Bolt Dia. & Length (In.)	Net. Wt. (Lbs.)	EPA (Sq. Ft.) At Pole Top				EPA (Sq. Ft.) 2' Above Pole Top				Max. Fixture Load—Include Bracket (Lbs.)
MH			S	BC	BP	B	D x AB x H		70	80	90	100	70	80	90	100	
30	SSS5A30S	.120	10 1/2	11.0	4 1/2	5	3/4 x 25 x 3	293	8.2	4.6	2.1	--	7.7	4.3	2.0	--	300
30	SSS5M30S	.188	10 1/2	11.0	4 1/2	5	3/4 x 25 x 3	369	15.2	9.5	5.8	3.1	14.2	9.0	5.4	2.9	300
30	SSS6A30S	.120	12 1/2	12.5	5	6	1 x 36 x 4	347	14.0	8.7	5.0	2.5	13.1	8.2	4.7	2.3	300
30	SSS6M30S	.188	12 1/2	12.5	5	6	1 x 36 x 4	505	26.4	18.1	12.5	8.4	24.7	16.9	11.6	7.9	300

Pole Model No. Marginal SSS6A30SFZ2 – 5.0 EPA, 300 lbs.
 Alternate SSS5M30SFZ2 – 5.8 EPA, 300 lbs.

There are strong arguments for selecting poles with ample EPA capacities. The 'in-place' cost differential is slight when compared to the overall cost of the installation and provides a safety margin.

Example 2

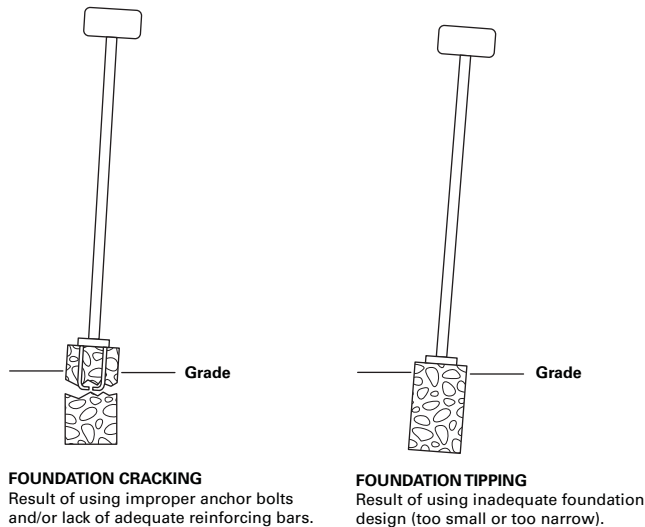
Job Name	Hoosier Mall
Agent	BBB Lighting
Job Location	Indianapolis, IN
Wind Speed (Use Iso-tach Wind Map—50 yr.)	90 mph (Near or between zones, use highest)
Luminaire Model	Acura Large Flood [ALF]
Quantity / Orientation	2 mounted on a T2B bracket
Pole Height	35 ft.
Luminaire Mounting Height (MH)	37 ft. (fixture located above the pole top)
Pole Style	Round Tapered Steel [RTS]
Luminaire(s) EPA	7.40 sq. ft.
Bracketry EPA	0.78 sq. ft.
Total EPA	8.18 sq. ft. (2 feet above pole top)
Luminaire(s) Weight	142 lbs.
Bracketry Weight	9 lbs.
Total Weight	151 lbs.

Mtg. Height (Ft.)	Catalog Number	Wall Thickness (Ga.)	Base Square (In.)	Bolt Circle Dia. (In.)	Bolt Proj. (In.)	Shaft Size (In.)	Anchor Bolt Dia. & Length (In.)	Net. Wt. (Lbs.)	EPA (Sq. Ft.) At Pole Top				EPA (Sq. Ft.) 2' Above Pole Top				Max. Fixture Load—Include Bracket (Lbs.)
MH			S	BC	BP	B	D x AB x H		70	80	90	100	70	80	90	100	
35	RTS8A35S	.120	12 1/2	12.5	5	8.4 x 3.5	1 x 36 x 4	342	23.0	17.3	13.5	10.5	21.7	16.4	12.7	9.9	400
35	RTS9D35S	.180	12 1/2	12.5	5	8.4 x 3.5	1 x 36 x 4	482	38.9	29.6	23.2	18.3	36.8	28.0	21.9	17.3	400

Pole Model No. RTS8A35SF— 12.7 EPA, 400 lbs.

If the job site is in an area which has had a history of vibration problems, or has open terrain and prevailing winds which likely may cause pole vibration, model number RTS9D35SF would be a better choice.

Note: When selecting a pole it is best to err on the conservative side. Because of the unknown and complex interactions of variables such as terrain (*location*), prevailing winds, pole geometry, and luminaire configuration, first and second mode vibration may arise putting additional and unpredictable forces on the pole.



Anchor Bolts and Light Pole Foundation

Anchor bolts are the most commonly used method to secure poles to concrete foundations. Their diameter and length are specifically selected to withstand load limitations listed in the catalog for each pole. The concrete foundation must be designed by a qualified engineer with knowledge of local soil conditions to provide sufficient strength to transfer the wind loads to the ground. Steel reinforcing bars are sized to prevent cracking and failure and with dimensions large enough for the soil to resist the overturning moment (OTM). Small, undersized foundations may cause the pole and foundation to rotate and lean. Cooper can provide the loading conditions (OTM, weights and torsion) for foundation engineers, but does not provide foundation design services.

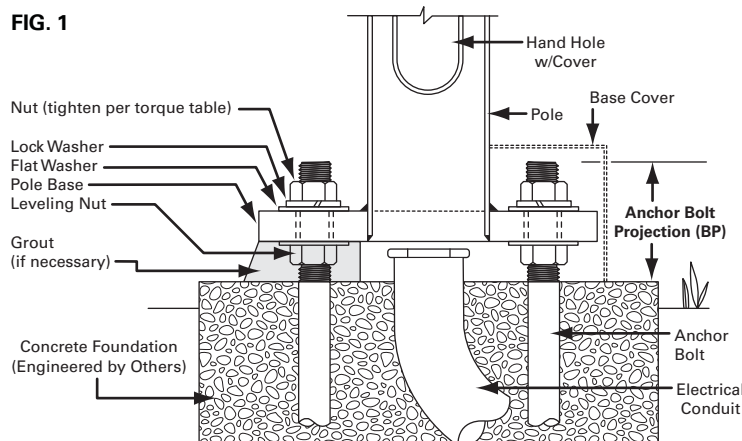
In addition to supporting the pole and fixtures, the foundation carries electrical conduit(s), providing power to the luminaire. If more than one conduit is used, it is important to keep the conduits clustered in the center of the bolt circle and minimal protrusion above the surface of the foundation as indicated on the template. Before pouring a concrete foundation, it is of utmost importance to ensure that:



Bolt Circle Template

- The bolt circle template conforms to the bolt circle of the pole base.
- The radial orientation of the anchor bolts is positioned properly relative to the hand hold position and the side of the pole where the luminaire is to be located.
- The anchor bolt projection (BP) is appropriate. Anchor bolt projection is the height the anchor bolt protrudes above the concrete surface (see FIG 1). If the anchor bolts have inadequate projection the pole may not be secured adequately. If the anchor bolt has too much projection the bolts may be subject to unwanted bending stresses and the base cover may not fit properly. Other manufacturers' anchor bolts or existing anchorage should not be used without prior written consent from Cooper Lighting (see page 11 for data worksheet for pole selection).

FIG. 1



Pole Installation

When erecting poles it is necessary to 'plumb' the pole. This can be accomplished easily with an accurate level and the supplied leveling nuts and washers. Once the pole is level, use a torque wrench to tighten the anchor bolts to the torque values listed in the pole instruction sheets.

A qualified electrician is required to perform the installation in compliance with the National Electrical Code (*NEC*) and other local codes. Proper grounding is required—an anchor bolt may not be used as a ground. The strain relief loop supplied on the pole nut plate should be used to prevent chaffing or abrading of conductors or putting tension on the conductor connections.

Poles with leveling nuts, where the base is elevated slightly above the concrete foundation, may be grouted with a non-shrink cement grout. The grout is installed in the space between the base and the foundation. However, grout is usually not required for poles using a base cover. The open space created by the base cover allows ventilation inside the pole, drying any moisture and condensation, thus reducing the possibility of corrosion. If grout is used, a condensation drainage channel should be provided. If rodents are problematic for the application small wire screens can be installed to prevent access to and gnawing on conductors.

Maintenance

Inspections of installed poles should be conducted regularly with a minimum prudent schedule of one week after installation, one month after installation, 6 months after installation, and annually thereafter. It also would be advisable to check the installation after any major wind event. During the inspection be sure to check poles for cracks. Cracks, although very rare, are usually located in the base weld, adjacent to the weld area, around the hand hole or at the corners of square poles. These cracks may be caused by vortex shedding vibration resulting in fatigue stresses. Over time and thousands of cycles, although small in amplitude, this rapid flexing vibration may produce small cracks in and around pole weldments. In time these small cracks grow until they become sufficiently long to cause the pole to fail. In addition to inspection of the pole itself, the entire system requires regular maintenance.

- Recheck the torque of the anchor bolts as the bolt/nut connections may relax slightly after the pole has been subjected to wind loading.
- Check for missing base covers and pole caps. Replace as necessary.
- The area around and underneath the pole base should be kept clean in order to help reduce moisture and minimize corrosion.
- Check the pole for corrosion and deterioration of the finish. Take remedial action to correct.

The Effects of Pole Vibration

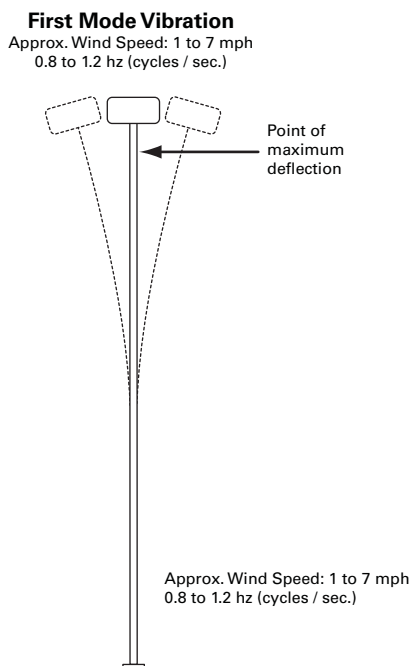
Light poles can be described as vertical cantilever structures. As with all structures they will vibrate under the right conditions in different modes and at different frequencies. Several types of outside forces may excite the pole and start vibration, the most common of these is wind. For example, poles mounted on a bridge may be subject to vibration due to wind blasts from passing trailer trucks or receive traffic-induced vibrations from the movement of the deck. Once the excitation force has been removed the vibration decays and the pole stops vibrating. Vibration in different structures decays at different rates called the dampening coefficient. Some poles have low dampening coefficients, and vibrate with less force and for a longer period of time after the force has stopped. Slender, flexible poles that have low dampening characteristics vibrate more readily and longer than stiffer poles.

There are situations where poles, under certain combinations of pole geometry, prevailing winds, site terrain and type of luminaire, may exhibit a type of vibration known as vortex shedding vibration. Due to the complex combinations and interactions of these variables, it is impossible to predict with certainty when and which poles will vibrate.

Vibration results in the pole moving back and forth. Sometimes to a large extent, sometimes a minute amount, this movement or displacement results in a stress to the pole. The stress is at its maximum at the bottom of the pole, as the displacement increases so does the stress. When these stresses are repeated they are called cyclic or fatigue stresses. While these stresses may be small in magnitude, when applied thousands and even millions of times they may lead to stress cracking in the pole (*pole vibration may also lead to failures in luminaire and lamp components as well*). Poles may vibrate up to 8 cycles per second, so it is easy to see how millions of cycles of stress can build rapidly over just a few weeks or months. Fatigue stresses are amplified in areas of discontinuity such as the tube and base plate connection. A small crack may develop after a period of time and many stress cycles. Following the initiation of a stress crack, the crack will continue to grow until the pole is no longer capable of withstanding even a modest wind event.

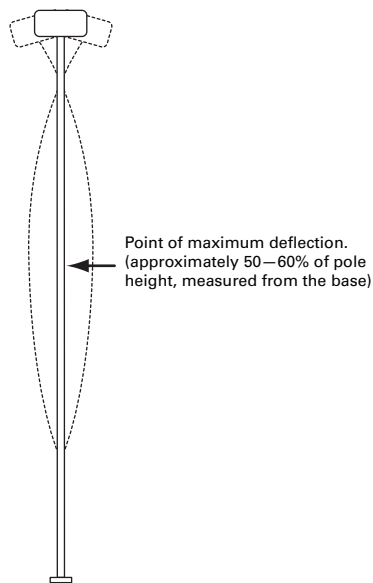
First Mode Vibration—Sway

First mode vibration occurs at low wind speeds and continues with increasing motion as wind speed increases. Its frequency is low (about 1 cycle per second). The maximum deflection occurs at the top of the pole and is rarely a problem. However, under high gusting conditions, more severe first mode vibration may result. When gusts occur in the 50 to 70 mph range, violent whipping and buffeting may result producing high repetitive stresses in the pole. These weather conditions do not occur frequently and are usually short-lived. The pole deflection is in the same direction as wind gust.



Second Mode Vibration

Approx. Wind Speed: 8 to 20 mph
3 to 8 Hz (cycles / sec.)



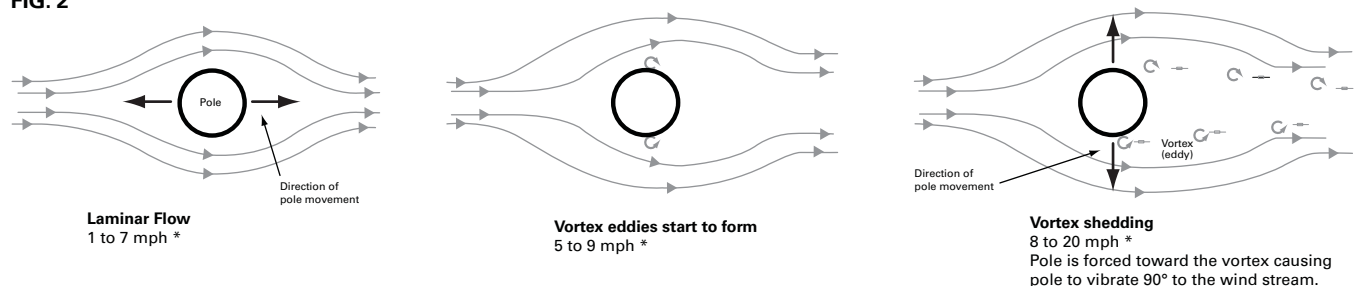
Second Mode Vibration—Vortex Shedding

Of first or second mode, second mode vibration is of the most concern. Second mode vibration is caused by a phenomenon known as vortex shedding. Vortex shedding is the alternating of small eddies spinning off the sides of the pole (*for example, a canoe paddle creates a vortex at each end of the blade*). There is a pressure collapse when a vortex is created, driving the pole in the direction of the vortex. Alternately, when a vortex is released from the opposite side, the pole is driven to that side. Thus the pole is forced back and forth at 90° to the wind direction. (See FIG. 2)

Vortex shedding frequency increases with wind velocity. When the vortex shedding frequency starts to approach the natural second mode frequency of the pole, the pole frequency and the vortex shedding frequency 'lock-in' causing the pole to vibrate.

This resonant condition occurs at wind speed between 8 to 20 mph with frequencies of 3 to 8 cycles per second. Unlike first mode vibration, the location of maximum displacement occurs at or near the middle of the pole. The pole vibrates 90° to the wind stream with low stresses but at high frequencies. As discussed, these stress cycles can build rapidly into the thousands and millions over time. Although these stresses are low, they may exceed the metal's fatigue stress endurance limit at stress concentration points such as base connections, welds, areas adjacent to the weld, corners of square poles, hand holes, etc. Fatigue cracks may develop and over time grow long enough to cause the pole to fail. Nearby trees and buildings tend to disrupt the flow patterns which cause vortex shedding vibrations.

FIG. 2



NOTE: * MPH will vary with pole diameter, pole length and air conditions (temperature, humidity—viscosity).

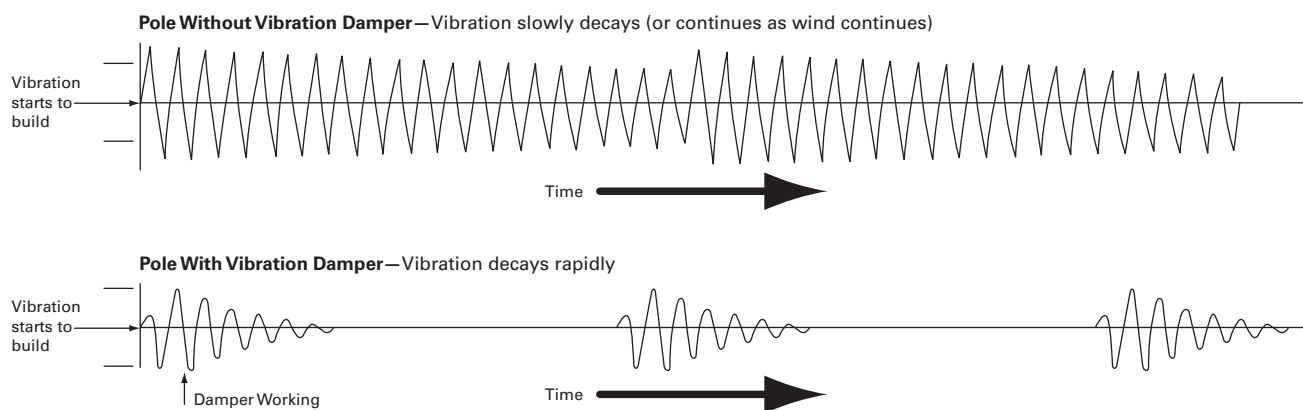
How to Detect Vibration

In first mode, the pole merely sways. This is usual and not damaging to the pole unless high wind and gusting conditions cause violent pole top displacement and whipping to occur. Second mode vibration caused by vortex shedding may be harder to detect. The amplitude of motion, located near the center of the pole, may be small and difficult to observe. A knowledgeable investigator needs to be at the job site when winds are blowing in the 8 to 20 mph range to witness second mode vibration. In addition to seeing the motion, one should be able to feel the vibration by placing a hand on the pole. The motion may also be accompanied by noise such as conductors slapping the inside of the pole. More sophisticated detection can be accomplished electronically by the use of accelerometers and recorders.

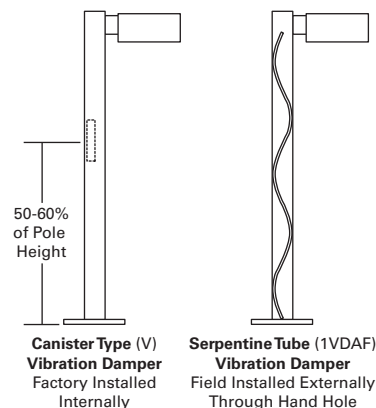
Suggestions for Avoiding Vibration

Both first mode and second mode vibration can occur at the same time and both types of vibration can lead to pole failure. It is best to check the job site terrain and conditions prior to ordering a pole. Poles located in flat open terrain or in exposed areas (*bridge decks, parking decks, airports, foothills, etc.*), where there are prevailing winds in the 10 to 20 mph range, may experience second mode vibration. For areas of concern round tapered poles are a better choice than straight poles, and steel poles are better than aluminum or fiberglass poles. Choose larger diameter poles with ample EPA capacities as they are stiffer and have better dampening characteristics than smaller cross section poles. For example, a 5" pole is a better choice than a 4" pole of the same height. Additionally, ensure that luminaires are installed at the time of pole installation.

There are a variety of methods and devices employed to reduce second mode vibration. These include mass-tuned vibration dampers, inertia dampers, viscous dampers and impact dampers. Even chains can be designed to suspend from the top of the pole to reduce vibration. These dampers function as energy absorbers, canceling the motion of the pole to reduce or eliminate vibration.



Most vibration dampers are effective for second mode vibration only and have little effect on first mode vibration. The type of dampener that is able to be employed will be determined by its time of installation. Internally mounted canister style vibration dampeners must be factory installed on made-to-order poles, while serpentine tubes or externally mounted canisters may be field installed when required. Select varieties of field installed dampers are mounted on the exterior of the pole and may detract from its appearance.



Poles are engineered structures designed to support luminaire configurations and withstand the physical forces of the application. Due to the number of factors that need to be carefully considered and the complexity of the environmental interactions, it is important to work closely with local code authorities and product design experts to properly design a pole fixture system capable of withstanding its application and environment.

APPENDIX

Common Pole Terminology and Definitions used throughout this paper with abbreviations.

EPA (Effective Projected Area)

Light fixtures or luminaires are rated in EPA (*effective projected area stated in square feet*) that refers to the apparent wind profile of a fixture or object considering for its geometric shape. For example, a round fixture, being more streamlined, has a lower EPA than a flat sided fixture of the same silhouette. For convenience, standard catalog poles list EPA capacity ratings based on wind speeds.

MH (Mounting Height in Feet)

The height at which a fixture is mounted above the base of the pole shaft. For example, floodlights may be mounted on brackets which may locate the fixtures above the height of the pole.

OTM (Over-Turning Moment in Foot-Pounds)

The bending moment caused by the wind force acting on the pole and fixtures which tend to topple the pole or foundation.

CSR (Combination Stress Ratio)

The ratio of the actual stresses imposed on a pole to the allowed stresses. These would include stresses due to the OTM, torsion forces, and axial (*or weight*) forces. The combination of all these stresses shall not exceed a CSR value of 1.0 (*100%*).

Torsion

Forces on a pole caused by the location of fixtures times the horizontal distance from the centerline of the pole (*measured in pound-feet*).

Vibration

A phenomenon which may occur under certain conditions causing the pole to oscillate rapidly. There are several modes of vibration, some of which may cause fatigue stresses severe enough to eventually cause damage to the pole and/or luminaire (*see page 6 for more information regarding the effects of pole vibration*).

Pole Geometry

The dimensional and physical shape of the pole. The basic characteristics are height, shape (*diameter or square dimension*), wall thickness, taper (*if any*), and weight. When combined with different loadings of luminaires and brackets, the same pole will exhibit different vibration characteristics.

Height Above Grade

Height from the surrounding terrain to the pole base (*For example, a pole located on a parking deck or bridge*). This is important because the wind velocity increases with elevation (*altitude*).

Breakaway Requirements

Breakaway requirements are usually mandated by the Federal Highway Administration for Interstate and State Highways. They also may be required on certain county and local road systems. Common Breakaway Devices are slip bases, certain cast aluminum T-Bases, and breakaway couplings. These devices are installed between the pole base and the foundation.

REFERENCES

AASHTO, (1994), *Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals*, American Association of State Highway and Transportation Officials, Washington DC.

AASHTO, (2001), *Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals*, American Association of State Highway and Transportation Officials, Washington DC.

Alcoa Structural Handbook, (1960), *A Design Manual for Aluminum*, Aluminum Company of America, Pittsburgh PA.

Delong Zuo, *Field Observations of Wind induced Lighting Pole Vibration*, Department of Civil and Environmental Engineering, Texas Tech University, M.S.,1023, Lubbock TX 79409.

Data Worksheet for Pole Selection

To ensure the best quality service when ordering / quoting a Cooper Lighting pole the following information should be collected. If, at any point, you have a question or need further assistance contact your Quotations or Technical Support Specialists.

Project: _____

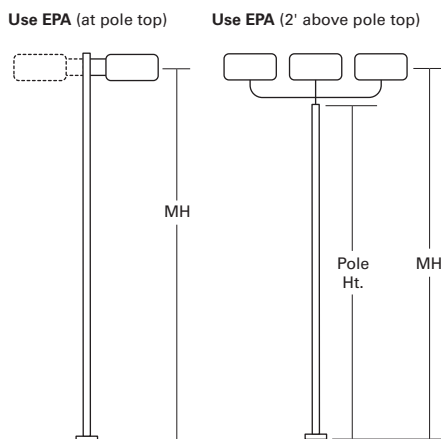
Location (city, state & zip code): _____

Wind Zone per Isotach Wind Map: _____

(if location is between zones chose the higher value)

Special Wind Zone or Terrain Requirements: _____

(indicate whether local codes specify special requirements or whether special terrain conditions exist such as bridge, overpass, parking deck, airport, mountain/foothill, open field or other areas with low steady state winds).



Pole Catalog Logic: _____

Or if catalog logic is not known choose from the following:

Geometry: ☐ Square Straight ☐ Square Tapered ☐ Round Straight
☐ Round Tapered ☐ Fluted ☐ Cruciform ☐ Hinged ☐ Other

Material: ☐ Steel ☐ Aluminum

Base Type: ☐ Standard Aluminum/Steel ☐ Direct Burial ☐ Hinged

Mounting Height: _____

Pole Height: _____

Height from Grade to Base of Pole Shaft: _____

Options: ☐ A=1/2" Hub¹ ☐ B=3/4" Hub¹ ☐ C=Convenience Outlet¹
☐ E=GFI Convenience Outlet¹ ☐ F=Vibration Pad ☐ G=Ground Lug
☐ H=Additional Hand Hole¹ ☐ J=Cable Support ☐ V=Vibration Damper
☐ L=Drilled for Bumper Glitter¹

Orientation to Hand Hole _____ Height above Base _____

Anchorage: ☐ New (add appropriate anchor bolts and templates to your order)
☐ Existing (consult factory)

Luminaire Mounting Configuration

Luminaire Catalog Logic: _____

Luminaire Mounting: ☐ Single Arm ☐ 2 @ 90° Arm ☐ 2 @ 180° Arm
☐ 3 @ 90° Arm ☐ 3 @ 120° Arm ☐ 4 @ 90° Arm
☐ Yoke ☐ Spider ☐ Tenon² ☐ Other

Luminaire Effective Projected Area [EPA]: _____

Luminaire Weight: _____

Accessory/Bracket Mounting Configuration (consult factory for banner and camera installation)

Accessory/Bracket Catalog Logic: _____

Accessory/Bracket Effective Projected Area [EPA]: _____

Accessory/Bracket Weight: _____

Accessory/Bracket Mounting Location: _____

Notes:

NOTES: 1 Must specify height above base and orientation relative to hand hole. 2 Specify tenon O.D. and height.

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