Wind Induced Vibrations on Light Standards

By Pete Manis, P.E., and Wes Jones, P.E.

The authors were recently involved in a project for which site work consisted of curb and gutter, sidewalks, parking lot paving, and light poles with foundations in the parking lot and along the roadway. Approximately five months prior to ribbon cutting, the client noticed that nearly all of the light poles were swaying considerably under wind velocities of approximately 17 to 28 mph, with gusts up to 46 mph. *Figure 1* illustrates the observed light pole movement, which had a magnitude of approximately 8 to 12 inches.

The very next day, the client discovered one of the light poles on the ground, with what appeared to be fatigue cracking at the weld between the light pole base plate and the pole itself (*Figure 2*). The client took down the remaining poles to prevent further failures. Fortunately, there were no injuries associated with the light pole failure, since this event occurred during the night when the construction crew was not present.

Review of the light pole submittal revealed that the subcontractor had proposed a different size and type of pole than what had been originally selected – a 30-foot tall, 6-inch square aluminum pole. Instead, the subcontractor proposed a 30-foot tall, 4-inch square steel pole, which was approved since the 4-inch pole more than adequately met the performance specification according to the manufacturer's literature.

Consultations with the light pole supplier and manufacturer indicated that the failure of the light pole was "most likely" due to wind-induced harmonic resonance of the light pole, and subsequent fatigue cracking of the weld between the base plate and the pole. The light pole manufacturer responded to a request for replacement light poles by saying that its standard one-year warranty does not cover "naturally occurring harmonic vibration light pole failures". Additional calls to various light pole manufacturers revealed that none of them warrant failure due to harmonic vibration.

It is important to note that the failed light pole met all of the manufacturer's requirements, and had been properly selected and installed based on their criteria. Many light pole manufacturers publish wind speed maps and light pole selection criteria for their products.

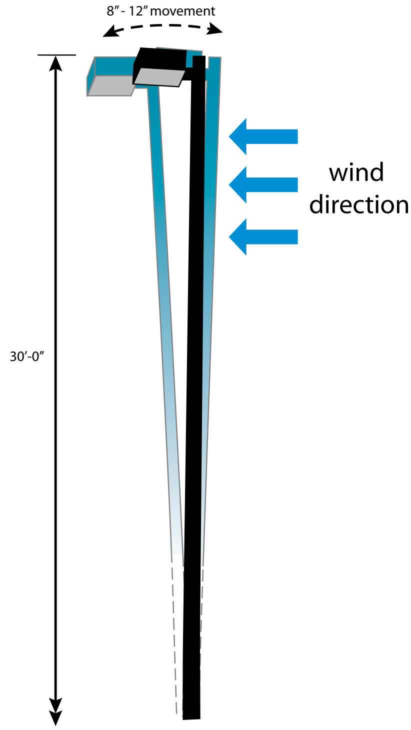

Figure 1: Observed light pole movement.

The following is a common light pole selection procedure:

1) Select the light fixture, and obtain its effective projected area (EPA) and weight. The EPA is the area that is loaded by wind. This information is located on the fixture cut sheet.
2) Determine the number of light fixtures and any special mounting methods (arm or bracket) to be installed on the pole. Obtain the EPA and weight for any arms or brackets from the corresponding cut sheets.
3) Add up the EPA and the weights of all fixtures, arms, and brackets.
4) Select the design wind speed for the project location from the light pole manufacturer's wind map. Typically, this is a fastest mile wind speed, which is different from the current building code values for a 3-second gust. Tables exist for converting between the two.
5) Select a pole, and compare both the EPA and weights of the fixture with the allowable EPA and weights for that specific pole. If the actual EPA and weights of the fixtures are less than the allowable EPA and maximum weight listed on the pole cut sheet, then the pole meets the requirements.

In the case of this project, the light poles met these criteria and yet still failed under the destructive effects of vibration under modest wind speeds; the design wind speed was 80 mph (fastest mile). In fact, when the wind speed matches the natural frequency of the light pole, there will "always" be resonance as a result. This will lead to fatigue cracking of the weld at the base plate to pole interface. Only in certain circumstances are light poles designed to resist fatigue, according to AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals* – specific "high level" lighting structures, along with overhead cantilevered traffic signal and sign structures. AASHTO indicates that common light poles do not normally exhibit fatigue problems, but as our example indicates, such failures can occur.

Rather than investing time and energy into fatigue analysis and mitigation in common light poles, a cost-effective approach is to minimize the probability of resonance by eliminating characteristics that enhance resonance. Two contributing factors to light pole resonance are height and fixture arrangement. One pole manufacturer indicates that light poles with a fixture EPA of less than 2.0 (very few fixtures) at a height of 25 feet or greater have an increased probability of resonance. While such a slender light pole can withstand the maximum design wind speeds, which generally are above 70 mph, it is susceptible to wind-induced vibration, which typically occurs around 20-40 mph.

As an example, consider the vibration of a flagpole exposed to wind. When there is no flag on the pole, it is quite common to hear cables "banging" against the pole. This is due to movement or vibration of the pole. However, when there is a flag at the top of the pole, the wind loading applied to the flag acts to dampen the resonant movement of the pole, eliminating the "banging" sound. (Incidentally, flagpoles have a different foundation anchoring system that typically does not include a base plate or welds. See the NAAMM *Guide Specifications for Design of Metal Flagpoles* for more information on flagpole design).

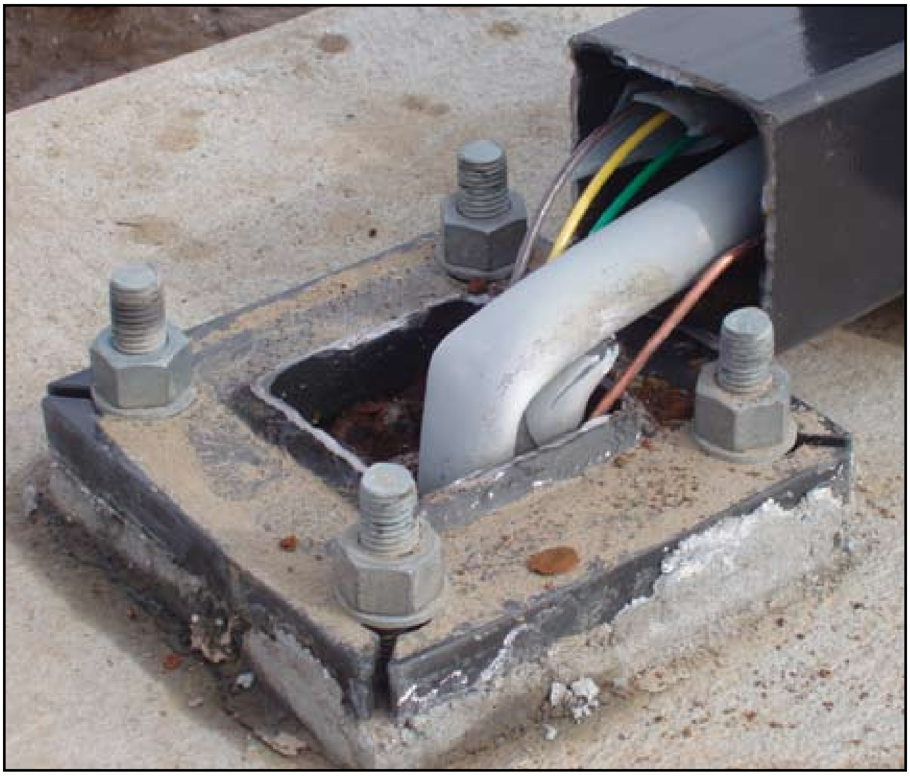

Figure 2: Light pole base failure.

Consequently, the use of shorter light poles with multiple light fixtures will generally reduce the chances of resonance. The shorter length provides a more rigid structure, and having more fixtures at the top equates to greater wind loading. This wind loading and the fixture weight at the top act as dampers to reduce resonant movement of the pole.

Additionally, although no shape is exempt from wind-induced resonance, it has been noted that round (or octagonal) tapered light poles are less susceptible to it than square ones. The natural frequency of a tapered light pole varies along its length, which makes it less likely to develop overall resonance from a constant wind. This is evident in the common types of poles used for highway lighting, flagpoles, and traffic control/signage structures.

Further, the geographic location of a light pole may also contribute to the steady-state, low wind speeds that result in light pole resonance. It has been noted that features such as unobstructed flat land or low-level mountains, where wind can be channeled through an area, may contribute to light pole resonance, as well as turbulence created by aircraft or vehicular traffic.

Many light pole manufacturers have attempted to minimize the problem of light pole resonance by offering factory- or field-installed dampers. A damper will essentially change the natural frequency of the light pole such that it will not coincide with a specific wind speed range. In many cases, these dampers are hanging weights that are installed either on the surface of the light pole or inside it. Dampers are not a cure-all for resonance, because they only change the range of wind speeds that can cause wind-induced resonance.

Based on the information above, the following recommendations have been collected from various light pole manufacturers' literature and should be considered to reduce the probability of wind-induced resonance:

1) Use round (preferably tapered) light poles less than 25 feet tall, with a 6-inch minimum diameter.
2) Use a minimum of two fixtures per pole to provide some weight at the top to help dampen the light pole.
3) Include in the pole specifications a requirement for factory – or field-installed vibration dampers to be provided by the light pole manufacturer.
4) Contact the light pole manufacturer when there are site-specific concerns that should be considered during light pole design.
5) Provide specific wind loading information in the documents, and indicate whether wind loading is based on a 3-second gust or fastest mile wind speed.

Periodic maintenance and inspection of a light pole can help determine if wind-induced vibration is a concern. Items to be inspected include the weld between the base plate and the light pole shaft and loosening or damage of the light fixture, as well as frequent lamp replacement. The client should be notified of the potential problem – possibly as part of a specifications-required O&M manual – and a maintenance plan should be implemented. If there is concern during periodic maintenance, the light pole manufacturer should be contacted, in addition to a structural engineer to assist in determining whether wind-induced vibration is the cause of the concern.

There is one more question: If harmonic resonance is prevalent during or after construction, who picks up the repair bill? Since the cause of wind-induced resonance is ultimately the wind, it is difficult to argue that the light pole manufacturer, contractor, client, or engineer is at fault. They can minimize the probability of wind-induced resonance, but not eliminate it. In this example, the light pole supplier replaced all 16 poles on the project. The project continued with minimal disruption thanks to the light pole supplier, whose personnel should be commended for their professional response to the issue. It is in the best interests of all parties involved to work together to minimize the probability of wind-induced resonance and to put in place measures to monitor any future concerns.▪

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References

1) Lithonia Lighting, "Light Standards Effects of Vibration Technical Bulletin"
2) AASHTO, "Standard Specification for Structural Supports for Highway Signs, Luninaires and Traffic Signals"
3) Valmont Structures, "Pole Owner's Manual, Warranty and Maintenance"
4) NAAMM "Guide Specifications for Design of Metal Flagpoles"