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Subject: Vibration and Fatigue Issues

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Vibration is a phenomenon that a pole structure may experience given a unique set of conditions. A structure will tend to vibrate, or resonate, when the natural frequency of the structure closely matches the frequency of the wind-induced repetitive external forces acting over a period of time. The natural frequency of a pole is a dynamic characteristic that varies for all shapes and lengths. A structure with a low natural frequency, at or below 1 hertz or cycle per second, is more susceptible to wind-induced vibration. The reason for this is the wind events act with a similar frequency. When the frequency of the alternating wind forces approaches the natural frequency of a structure, the structures amplitude of resonance and resulting stress on the pole significantly increase.

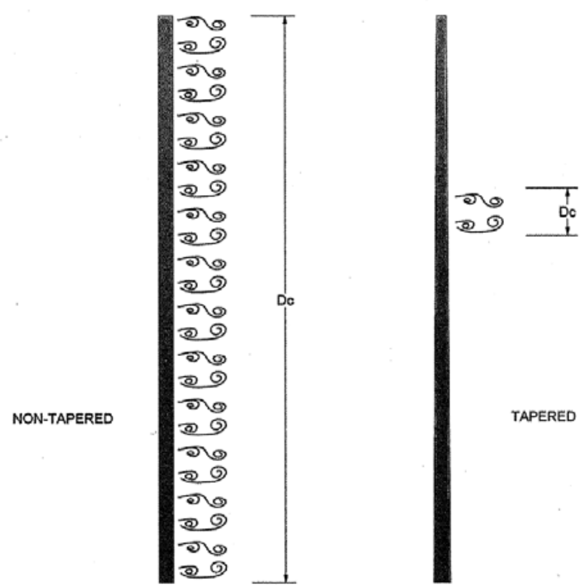
Many factors contribute to the likeliness of a vibration event occurring. Factors such as the surrounding geography, micro wind patterns, section characteristics, and loading all impact the probability of a vibration event. Unlike the ultimate wind design case for a pole structure, vibration occurs when wind is measuring at a low-velocity, steady flow. The wind velocity range with the highest probability of exciting a structure to resonance is typically less than 45 mph.

The most common geographic characteristic that can be attributed to vibration is an area of flat open terrain, or wind over open water where there is little to no obstructions to break up the flow of wind. These geographic characteristics are most commonly found in the central plains of the United States where there are large expanses of flat open land with limited obstructions.

The two types of wind phenomena that are the most common cause of vibration in cantilevered light structures are natural wind gusts and vortex shedding. Natural wind gusts are the constant, every day wind flow on a structure. Typically the wind velocity range is between 5-25 mph. The wind force from a natural wind gust will "push" on the upstream face of a pole, causing a cyclical bending moment and resulting in cyclical bending stresses at the base of the pole. The second wind phenomenon is vortex shedding. Vortex shedding is the result of wind acting on a bluff object where flow separation, or shedding, occurs alternately on each side of the object, thus creating alternating forces perpendicular to the direction of the wind (Fluid Structures)(see image below). When the frequency of these shedding forces approaches one of the natural frequencies of the structure, the amplitude of displacement increases, potentially resulting in high bending stresses in the supporting structure. This interaction is often repetitive over a short time period, creating a high quantity of stress cycles during each wind event.

Vortex formation in the wake of a bluff object

The critical wind speed at which vortex shedding occurs is a function of the diameter of the cross-section. Non-tapered pole structures are more susceptible to vortex shedding, as research from the *National Cooperative Highway Research Program 412* has shown. However, a tapered cross-section is less susceptible. For non-tapered structures, the diameter and associated critical velocity are continuous over an extended length, thus more readily allowing the poles resonance to, “lock-in” with the wind. In contracts, the critical velocity for tapered structures is variable along the pole length with discrete critical velocities only occurring over short distances. This variable range of critical velocities makes it difficult for the lock-in condition to occur.



The vibrations from the two phenomena, described above, will result in repetitive stress cycles on the structure. The resultant stresses are much lower than the allowable stress that the structure is designed for under a peak static design wind load, typically between 90 and 150 mph.

However, the probability of a structure experiencing full loading due to a peak design wind load is once in 10-50 years, whereas the probability of a structure experiencing high cycle loading due to natural wind gusts or vortex shedding is much higher. A vibration event will result in displacement cycles at a frequency of about 1 cycle per second. This highly repetitive stress can develop into a fatigue issue.

Materials, such as steel and aluminum, have variable fatigue life-spans depending on the stress magnitude and the number of cycles. The characteristics of different cross-sections will magnify the stress values due to concentration affects. Cross-sections with abrupt corners, such as a square section, will induce a higher stress value in the corners when compared to a round section. The stress concentration at that corner is a fatigue concern under a repetitive loading situation.

Due to structures having little natural dampening, the luminaires that are attached to the pole provide a great benefit in enhancing the dampening characteristics of the structure as a whole. With this in mind, as well as the potential severity of vibration problems, all pole structures should be installed with the luminaire fixtures attached. While an unloaded structure has less effective projected area (EPA) to attract the wind, the structure also has minimal dampening to stop the vibration. Additionally, as the industry adopts new fixture technologies the fixtures are reducing in size which results in minimal EPAs. The reduction in EPA can cause the pole to act as if there is no luminaire at the top in terms of dampening. The smaller fixture profiles can increase the potential for vibration and fatigue issues in the structures.

Dynamic effects on a pole are not straight forward to control. The best solution is to utilize a product that reduces the stress concentrations and stress levels if vibration were to occur. As previously discussed, a square cross-section will result in a higher stress level due to the stress concentrations at the corners. Therefore, a round section is the better option in terms of fatigue resistance. Additionally, a tapered section will better mitigate the potential for vortex shedding. Mechanical dampeners such as chain dampeners or canister dampeners will effectively alter the dampening characteristics of a structure and have been proven to be effective in many situations. Finally, by properly installing a structure, which includes proper tightening of the anchor bolts and installing the fixtures at the same time as the pole structure, fatigue issues can be reduced.

By understanding the negative effects of vibration and properly selecting the right product type for the situation, fatigue related issues due to vibration can be minimized. Unfortunately, vibration and the resulting fatigue issues are difficult to predict with any degree of certainty due to the unknown and variable nature of the characteristics causing them.

Incorporating effective practices during selection, properly installing and monitoring the structures after installation will provide the best defense against vibration related problems.

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