AEROACOUSTIC ISSUES OF BUILDING ELEMENTS

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1 Introduction

During high wind events, certain building elements have the potential to generate significant tonal noise that can be heard miles away. These aeroacoustic issues are due to an interaction/coupling between an unstable fluid flow and a feedback mechanism. Aeroacoustic issues are often easy to avoid when susceptible geometry can be identified during the early design process, but mitigation can be technically difficult and very costly once issues do occur. Because aeroacoustic issues are unique and often annoying, they are often considered newsworthy and can be the subject of significant publicity.

2 Aeroacoustic mechanisms

Typically, wind-induced noise from architectural elements arises from one of three main mechanisms: vortex shedding over a bluff body, cavity resonance, or flow through repeated perforations/slotted openings. Although these mechanisms usually occur independently, in specific situations two or even all three of these mechanisms may work in combination.

Each of these three mechanisms are initiated by a flow instability at which alternating flow, or vortices, shed from one side to the other. As the wind speed increases, so too does the rate of the alternating flow. When the frequency of the shedding gets close to the frequency of resonance, they lock together which may result in the generation of significant tonal aeroacoustic noise.

2.1 Vortex shedding

Wind flowing around a bluff body, or a non-streamlined object, such as a cable, railing, beam, plate, panel etc., has potential for tonal noise due to vortex shedding.

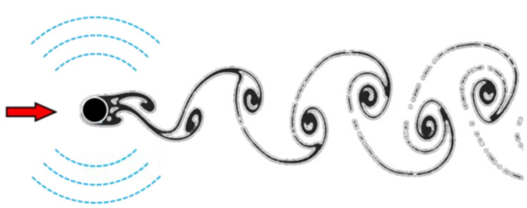

Figure 1: Illustration of vortex shedding off a cylinder.

As the wind alternates, forces are imparted on the structure. This is especially a concern where the vortex shedding frequency matches a structural resonance or acoustic mode. As a result, vibration/noise can then be radiated in one of two ways as illustrated in Figure 2.

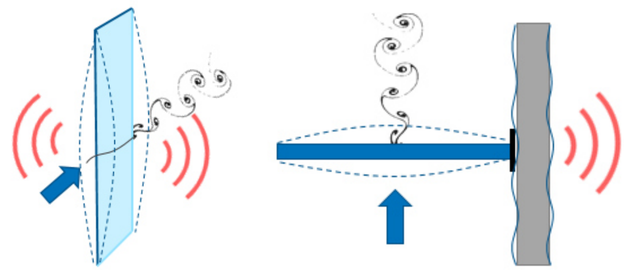

Figure 2: a) Object is large enough to radiate noise as vibration. b) The bluff body transmits vibration to a connected structure, which radiates the noise.

a) If the object is large enough, it may alone radiate vibration due to vortex shedding as noise. This is similar to the way the reed/mouthpiece vibrates and generates noise for a woodwind instrument.
b) The vibration of the bluff body may be transmitted to a connected structure, which in turn, may radiate noise. This is similar to the vibration of the guitar string transmitted to the body of the guitar, which radiates the noise.

2.2 Cavity resonance

Wind flowing across the opening of a slot or cavity can create a strong tone similar to blowing across the pan flute or open bottle. For cavity resonance, the air flow is alternating into and out of confined volume of air, similar to blowing over the top of a bottle. Common cavity geometries encountered on buildings include window mullions, stacking joints, and building maintenance tracks.

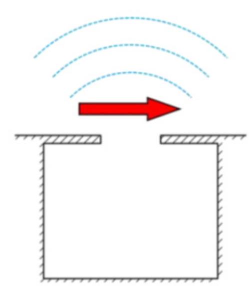

Figure 3: Illustration of flow across a cavity.

2.3 Perforation noise

Wind flowing across or through a repeated perforation pattern can create a reinforced tone-like noise due to the repeated geometry. This may result in an amplification and

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synchronization of a number of separate perforated panels. In these instances, low noise sources (individual holes) may combine to create significant sound pressure levels. Perforated panels are often used as elements of a cladding system, or a part of a sunshade, balcony, or catwalk.

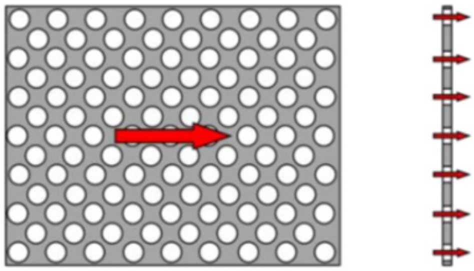

Figure 4: Illustration of flow through and across a perforated plate.

3 Assessment of risk

In order for aeroacoustic noise to be generated, three conditions must be met:

1) The building feature must be capable of one of the three mechanisms,
2) The wind must flow past the feature/geometry with the right direction and speed,
3) The frequencies associated with the interaction must be within the audible range.

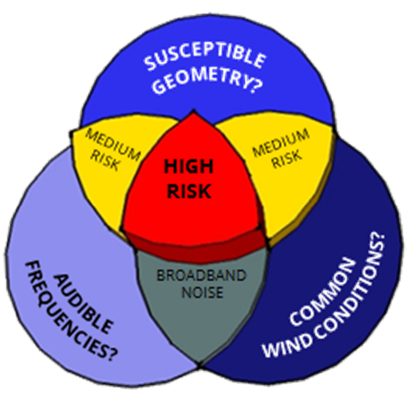

Figure 5: Three required conditions for the generation of aeroacoustic noise.

3.1 Local wind conditions

Wind-induced noise phenomena occur strongest at certain wind speeds and wind flow directions with respect to the architectural feature. Wind speed also varies predictably with height, so these wind speeds can be adjusted to whatever the height of the building or the element is.

Therefore, knowledge of the local wind climate helps to determine the associated risk as we can assess what problems might occur within a reasonable range of common wind speeds. If the right wind conditions are expected for only 1 hour/year, there may not be concern.

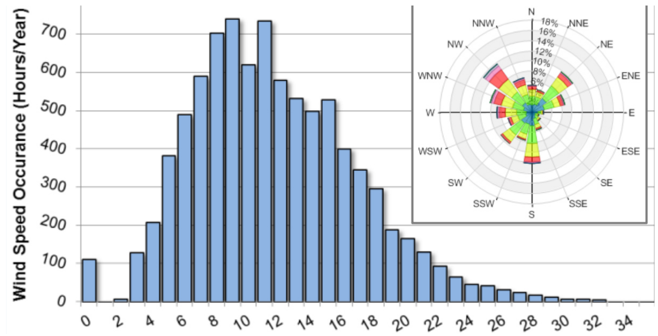

Figure 6: Example of historical wind data (speed and direction) in a specific wind climate.

3.2 Audible frequencies

Pressure oscillations or objects vibrating in moving air can occur at any frequency, but only those in the range of 20 to 20000 Hz are potentially audible. Moreover, people are less sensitive to noise as the frequency nears the upper and lower frequency limits

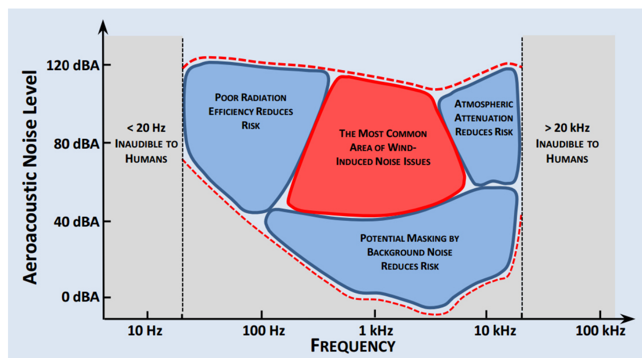

Figure 7: Frequency and its relationship with aeroacoustic issues.

The frequency of noise has an associated wavelength. For a building element to radiate noise efficiently, the dimensions of the element should be comparable to the wavelength of noise. For this reason, we can rule out many architectural features based on their dimensions. For audible noise generation, an architectural feature must have dimensions:

- Approximately less than 3 m for cavity resonance;
- As a general rule of thumb, any flexible spans, approximately 650 mm in diameter or less, have the potential to generate noise caused by vortex shedding.

Audible sounds having many frequencies at once, such as wind blowing through trees (broadband spectral sound) is often less annoying because it blends into the background noise, whereas sound consisting of one main frequency, or tonal noise tends to stand out. Thus, when assessing the risk of features in generating aeroacoustic noise we are generally assessing the likelihood of the feature generating strong tonal noise.