Whistling Building Objects, Origins and Solutions

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INTRODUCTION

Sincere complaints occur during periods with high wind velocities when high tonal sound levels are caused by specific parts of objects, mostly grating. Practical cases were analyzed, using the acoustical laboratory facilities of Peutz. From this a special measurement program was derived to obtain more systematic knowledge of this phenomenon. Moreover, practical provisions to reduce this kind of sound were studied.

THEORY

The aeolian tone is a monotonic aerodynamic sound generated by an air flow around an object due to shedding of vortices. The frequency of the aeolian tone is related to the dimensionless Strouhal number S:

$$f = S \cdot \frac{v}{D} \qquad (1)$$

with:

f	(oscillation) frequency [s^{-1}]
D	characteristic dimension of the object perpendicular to the air flow [m]
V	velocity of air flow in front of object [m/s]

This formula shows a direct dependency between frequency and air flow velocity, which provides a good description of aeolian tones. Often this concerns phenomena in the lower frequency range related to common dimensions of obstructions in air flows. The tones described in this paper are mostly in the higher frequency range and depend on a different way on the air flow velocity.

PRACTICAL CASES

In different practical situations high sound levels with a tonal character have been observed during specific wind conditions. See for instance figure 1, showing sound levels as observed in practice.

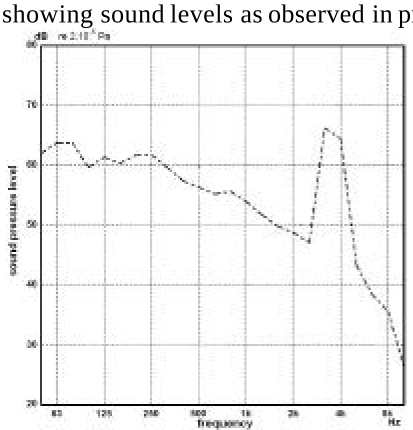


Figure 1: Spectrum of sound level (about 70 dB(A)) of grating in practice at a distance of about 80 m.

SYSTEMATIC MEASUREMENTS IN LABORATORY CONDITIONS

Origin of sound levels

It has been checked whether the sound levels are really aeolian tones and do not originate from radiation of vibrations of the gratings. Figure 2 shows the sound levels due to air flow through the grating as well as the vibration levels on the gratings. These spectra show that vibrations of the grating due to excitation by a hammer respectively by the air flow are dominant below 4000 Hz, with main peaks below 2500 Hz. Aeolian tones appear above 4000 Hz for this type of grating. Therefore it is clear that the high sound levels are air flow induced.

Sound and vibration measurements on grating 1 of high rise building 1

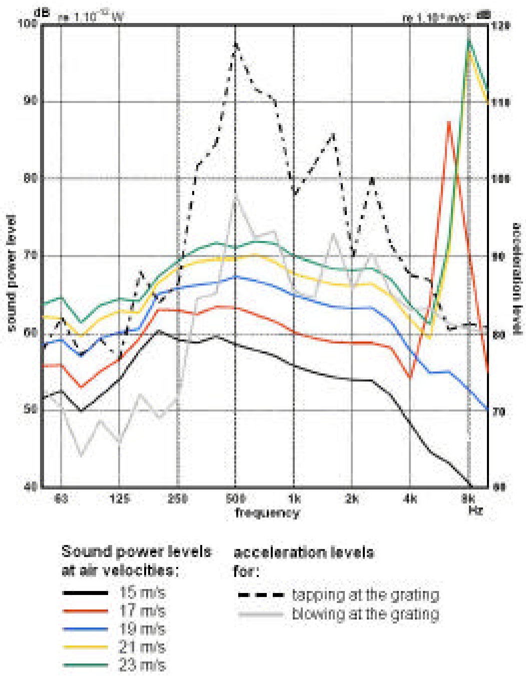


Figure 2: Spectral sound power levels and acceleration levels of grating 1 of building 1

PARAMETERS OF INTEREST TO BE INVESTIGATED

Because grating bars perpendicular to the air flow are the main cause of aeolian tones, this study is mainly directed at the bearing bars, of which different heights are considered.
Practical situations showed that the distance between the bearing bars is of influence on the occurring sound levels.

Therefore a test grating was designed, of which the distances could be varied without changing other parameters. Based on common practice a thickness of 2 mm for the (galvanized) steel of the bearing bars has been used.
Sharp edges of the steel bearing bars have been used since practice showed that rounding the edges decreases the generated sound levels.

MEASUREMENT SET UP

In the acoustical laboratory of Peutz in Mook "silent air" is available. For this specific research the velocity of the air flow was variable from 0 up to about 30 m/s.

Figure 3 shows the test grating designed to determine the influence of height and distance between bearing bars, as well as the sharpness of the edges and the angle of attack of the air flow. The distance between bearing bars could be changed with intervals of 1 cm. The height of the studied bearing bars is 20, 30 en 40 mm. When at a certain air velocity an aeolian tone is observed for the first time, the angle of attack is changed in small steps.

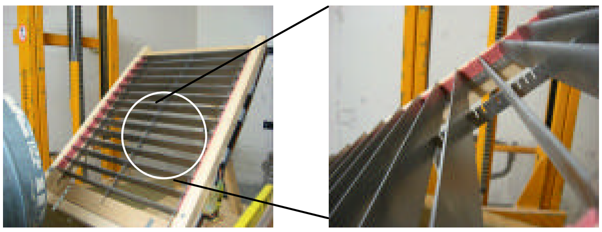


Figure 3: The test grating

MEASUREMENT RESULTS

In figure 4 measurement results regarding the test grating with bearing bars with a height of 40 mm and varying center to center (c.t.c.) spacing of bearing bars of respectively 30, 40, 50 en 60 mm are shown. The angle α of the air flow in this specific case is 26°, at which the aeolian tone is at its loudest. In the following only some representative results regarding this phenomena are presented.

Figure 4a shows a clear peak at an air flow of 27 m/s in the 3150 Hz third-octave band. At an air flow velocity of 25 m/s two peaks are observed, in the 3150 and 10000 Hz third-octave bands. These tones alternate in time, as can be seen from figure 5, showing the sound spectra as function of time.

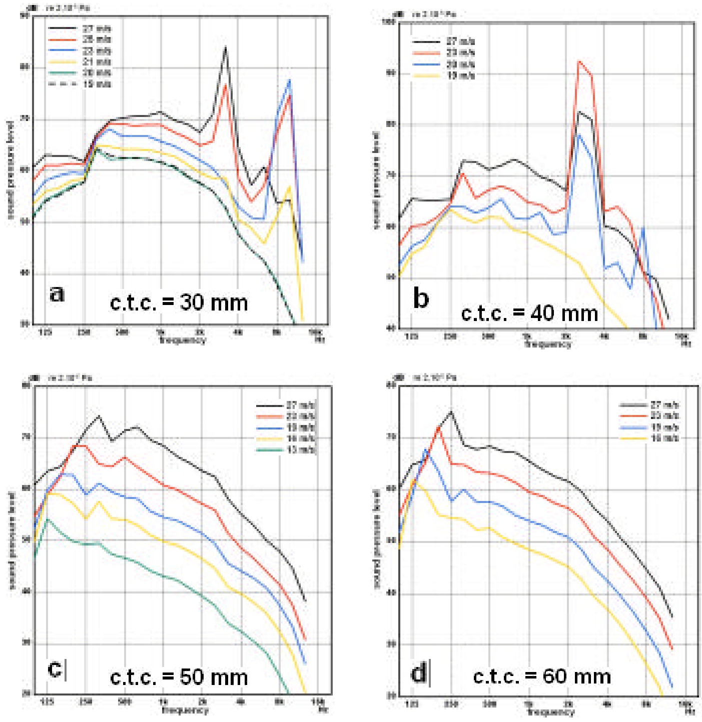


Figure 4a-d: Measurements on the test grating with a bar height of 40 mm.

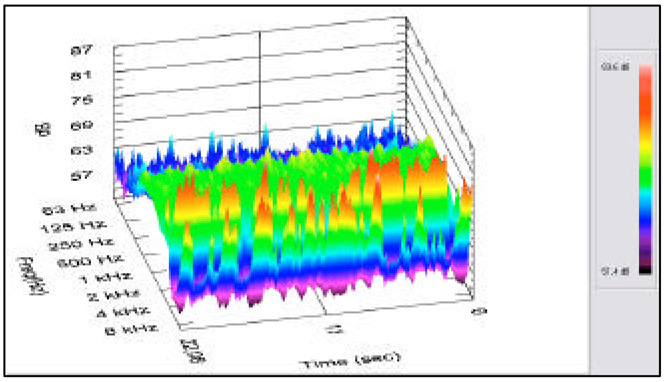


Figure 5: Spectral sound power levels as function of time for grating with bearing bars height / distance of 40 mm / 30 mm at an air velocity of 25 m/s

With air flow velocities below 20 m/s no tone is observed anymore. At c.t.c. spacing of respectively 50 and 60 mm no tone at higher frequencies is observed; see figures 4c and 4d. This also applies to other angles of attack.

Figure 6 deals with an angle a = 26°. Figure 6b gives the results with the grating tilted to 38°. Figure 6a shows a clear peak in the 3150 Hz third-octave band, at air flows from 27 to 23 m/s with no significant change in sound level. At 22 m/s the tone disappears. At 16 m/s two tones are observed in the 3150 and 6300 Hz third-octave bands with a relative low sound level.

At air flows lower than 16 m/s no tones occur. Changing the angle of attack to 38° the tone in the 3150 Hz third-octave band only remains at higher velocities.

Angle of attack = 26° **Angle of attack = 38°**

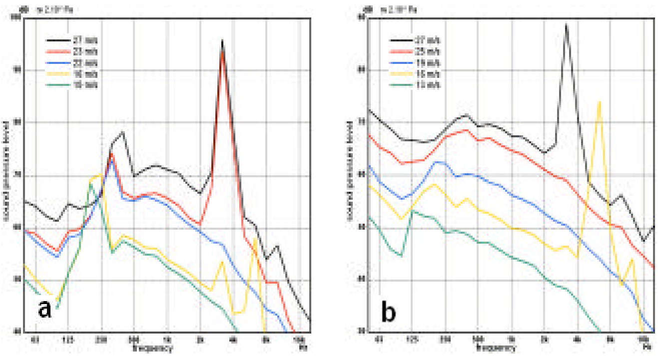


Figure 6a-b: Measurements on the test grating with a bar height of 30 mm and a c.t.c. spacing of 40 mm for two different angles of attack.

INFLUENCE OF THE AMOUNT OF BEARING BARS

The dependency of the number of bearing bars was tested, starting with 1 bearing bar and subsequently adding an extra bearing bar in the test grating. Only with 9 bearing bars an aeolian tone was generated at the same frequency as with the complete grating (see figure 7) This clearly shows that the repetitiveness of the bearing bars of the grating is very important in generating this specific type of aeolean tones.

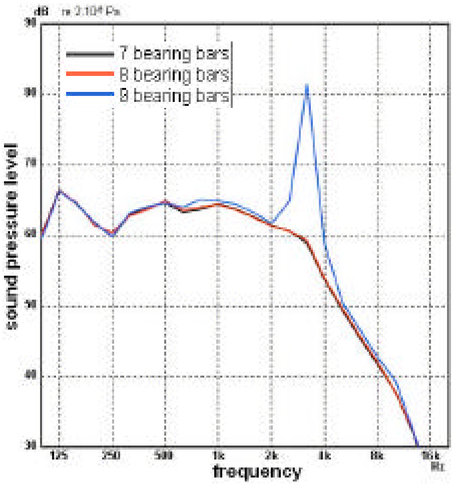


Figure 7: Dependency of number of bearing bars

SOUND REDUCING PROVISIONS

Rounding the edge

To determine the influence of rounding the edges of the bearing bars, tape was applied at the edges. See figure 8. It appeared that the treated bearing bars generate the loudest tone at a = 26° (see figure 8) at an air flow velocity of 27 m/s in the 3150 Hz third-octave band.

Figure 8: Bearing bars with tape-rounded edges

Grating with sharp edges (untreated) **Grating with tape-rounded edges**

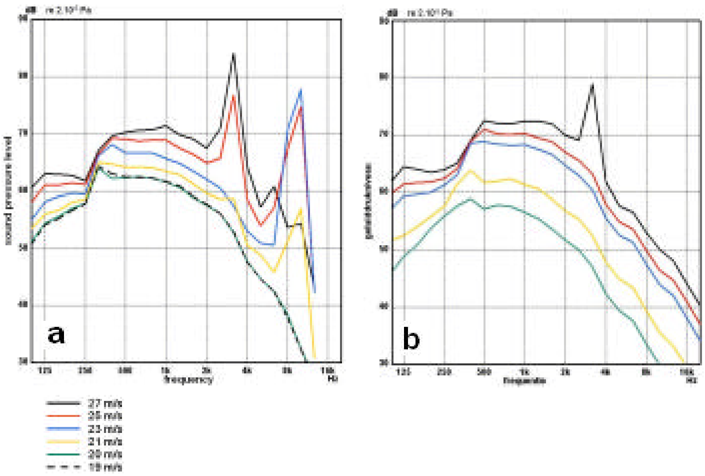
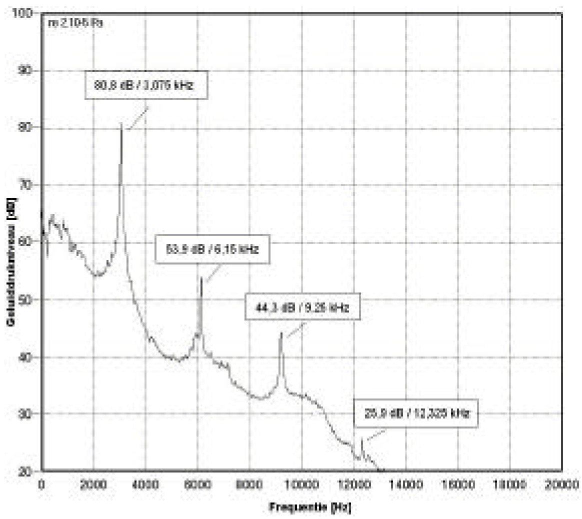


Figure 9a-b: Measurements on the test grating with a bar height of 40 mm with sharp edges (a) and with tape-rounded edges (b).

To see whether the same frequencies were involved, for both configurations a FFT was made, see figure 9 (in both cases with an air flow velocity of 27 m/s).

Grating with sharp edges (untreated)



Grating with tape-rounded edges

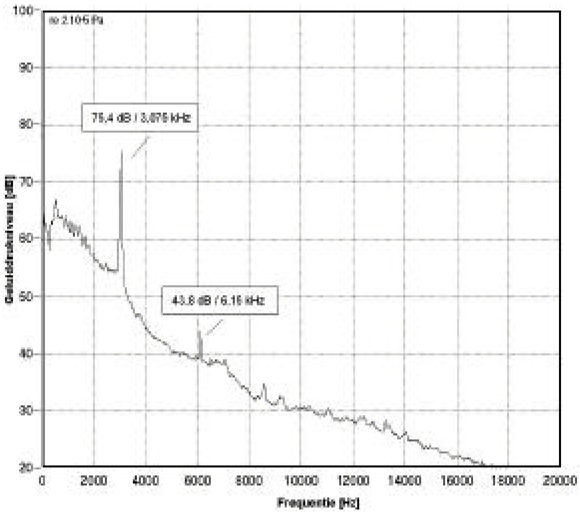


Figure 10a-b: FFT of measurements on the test grating with untreated sharp edges (a) and with tape-rounded edges (b); air flow velocity of 27 m/s.

Figure 10 shows that the frequencies remain the same in both configurations, but the sound level is decreased with approximately 5 dB in the treated situation. No observable tones below 25 m/s are generated in the treated situation.

Grating with net attachement

Measurements regarding a grating with a net attached (see figure 11) show that this provision sufficiently reduces aeolian tones.

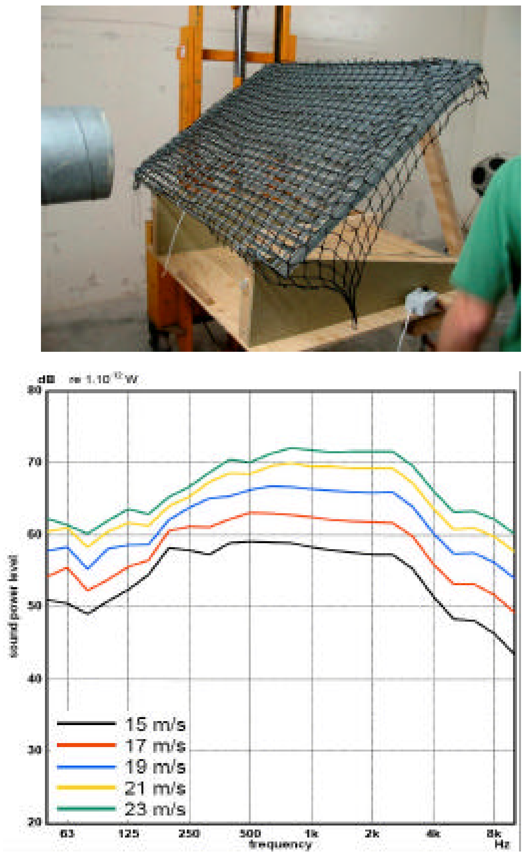


Figure 11: Grating 1 of high rise building 1 treated with a net attached to the under side and the measurement results for different air flow velocities.

CONCLUSIONS

Aeolian tones at higher frequencies are generated at gratings with air flow velocities roughly above 10 m/s (comparable with 5 Beaufort and higher). Within a certain range of air flow velocities no change of generated frequency occurs. Only the sound levels change. At a certain air flow velocity this frequency jumps to another value, to remain constant again in a certain range of air flow velocities. In specific situations two frequencies are observed, however not simultaneously but alternating in time. The repetitiveness of the bearing bars of the grating is very important in generating this specific type of aeolian tones. This seems responsible for the sound generation in the higher frequencies, since no aeolian tones are observed when only a small number of bearing bars are set in the air flow.

At all tested configurations no high frequency aeolian tones are observed form a c.t.c. distance between the bearing bars of 50 mm and higher; only aeolian tones occur at lower frequencies related to the air flow velocity in conformity with formula 1.

Rounding the edges has led to a significant decrease of noise generation. Investigation with alternative types of gratings with less or different repetitiveness of bearing bars are planned.