Design of acoustic windows with micro-perforated absorbers

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Abstract
The objective of this research is to develop a series of window systems that will reduce outside noise whilst allowing natural ventilation and also enable efficient use of daylight thus addressing growing concerns about sustainability. Initial measurements have demonstrated the feasibility and effectiveness of using transparent micro-perforated sound absorbers in the ventilation path of such window systems. A series of measurement is being made with a range of designs. This paper presents typical test results and discusses the optimum design configurations in terms of noise reduction, ventilation and daylighting.

1. Introduction
This research explores window systems that will reduce noise transmission whilst allowing natural ventilation and daylighting [1,2]. Silencer-type elements are applied using transparent micro-perforated absorbers (MPA). Due to the use of transparent materials, there is far more freedom when designing the system. The study considers the ventilation performance by focusing on the need to achieve occupant comfort by means of air movement, although the requirement for the minimum air exchange is also taken into account.

The data presented in this paper are based on an experimental set-up using a semi-anechoic chamber and a reverberation chamber. In addition to noise reduction, ventilation and daylighting tests are being carried out using the same test rig to assess the relative performance of different systems and examine the different potential roles each type could fulfill.

2. Micro-perforated absorbers
Compared with conventional perforated plate absorbers, an important feature of micro-perforated plate is that the acoustic resistance of the apertures, which becomes significant when the apertures are very small, needs to be taken into account. This means that for micro-perforated absorbers it is not necessary to provide extra acoustic resistance using porous materials. A micro-perforated panel (or membrane) mounted at a distance from a rigid wall makes a resonance system. By considering the acoustic impedance of the air behind the panel/membrane, the acoustic impedance of the whole system can be derived [3]. If the sound wave is incident upon the panel at an angle to the normal, the impedance of the air space may change due to the path difference between the incident and reflected waves, whereas the apertures are locally reacting acoustic elements, which means that the acoustic impedance is independent of the angle of incidence.

For a micro-perforated panel or membrane backed by an air space, simultaneous effects of the panel/membrane and the apertures should be considered. Adding additional layers of micro-perforated panel or membrane will tend to broaden the frequency range of absorption.

3. Test results of various configurations
The basic “open window” configuration (H000a) with two sheets of glass with a 260mm spacing is shown in Figure 1. The top and bottom openings are both 380mm. This configuration establishes a significant path for air movement whilst providing a channel in which to achieve acoustic attenuation.

Figure 2 shows the measured sound pressure level (SPL) difference between the source and receiver rooms, namely the semi-anechoic chamber and the reverberation chamber, achieved using four sheets of MPA fixed at set distances from glass sheets. In C006o the airspaces are 80mm and 10mm front and back and in C006p the airspaces are 80mm and 60mm front and back. These configurations provide a clear improvement in the SPL difference whilst still providing a significant clear ventilation route (100mm). For comparison the SPL difference achieved by a single pane of glass totally blocking the opening (i.e. a closed window) is also shown by B003f. Since the objective is to study the effectiveness and feasibility of MPA in a window system, a ready-available MPA has been used and the resonance frequencies are over about 1kHz.

Figure 3 shows the measured SPL difference where acoustic louvers instead of MPA sheets are added to the same window configuration. Five louver blades are added (although more are possible) and these provide roughly similar attenuation as the sheet MPA while using around 1/3 less MPA. The lines C006s, C006v and C006x represent different orientations of the louvers within the window. The advantage of louvers has over fixed sheet MPA is the ability to control solar gain more accurately.
Figure 4 shows the measured SPL difference where glass sheets are added to the basic configuration (i.e. no MPA sheets and acoustic louvers) to increase the length of the sound path and to create acoustic bends (see Figure 1). H001a is for an internal bend, H101a is for an external bend, while H201 adds both. There is a significant improvement over the basic configuration at the expense of a significantly wider window (100mm for each bend).

Figure 5 presents the measured SPL difference where the bends and the internal acoustic louvers are used. The result is clearly better than a sheet of single glazing over most of the frequency range, while still allowing free ventilation.

4. Conclusions

This paper has demonstrated that by carefully designing the configurations and by the use of MPA it is possible to create a window that combines sound attenuation with high levels of ventilation flow and illumination. There is a very wide range of options and it is probable that in most if not all situations where openings are required there is some variant that can be used.

5. References