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NOISE CONTROL FOR A BETTER ENVIRONMENT

Acoustically Treated Dual Vented Window System

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ABSTRACT

The aim of this research was to test the feasibility of an acoustically treated dual vented window system to control noise intrusion to buildings while providing natural ventilation. The design of the window system was based on replacing a standard double hung window with a simple, easy to operate, counterbalanced sashless window with two panes of glass allowing the ventilation opening size to be controlled by the user. Various configurations of the sashless window with different opening sizes and acoustic treatment options were tested in the Acoustic Laboratory at the University of Sydney in terms of sound transmission loss and pressure drop / airflow performance. Results indicate that significant sound transmission loss performance is achieved while still providing satisfactory airflow to the receiving room.

Keywords: Noise, Attenuation, Natural Ventilation
I-INCE Classification of Subject Number: 33

1. INTRODUCTION

Natural ventilation is widely accepted as a sustainable design strategy for buildings. The role of natural ventilation in buildings can be summarised as follows:

- Improve indoor air quality by decreasing the concentration of indoor air pollutants
- Improve thermal comfort conditions in indoor spaces
- Decrease the energy consumption of airconditioned buildings

The use of natural ventilation in buildings often conflicts with the control of ingress of external noise via the façade, because of the need to provide ventilation openings. In many projects, the use of natural ventilation is considered not feasible because of noise issues – either because the perceived high-noise environment cannot be controlled with practical measures to the noise level limits recommended in national standards, or that the capital cost of noise mitigation measures outweighs the benefits of natural ventilation.

One of the issues acoustic consultants encounter when considering the acoustic performance of naturally ventilated facades is the ability to quantify the sound insulation performance of these façades. While laboratory sound insulation test data is widely available for façade glazing typically used walls, little information is available for different configurations of openable windows and ventilated façades in general. This paper aims to provide test measurement data for various configurations of an openable dual vented window system to better understand the acoustic performance.

2. DUAL VENTED WINDOW SYSTEM DESIGN

The principles of the proposed dual vented window design are shown below in Figures 1 and 2. The design of the window system was based on replacing a standard double hung window with a simple, easy to operate, counterbalanced sashless window with two panes of glass allowing the ventilation opening size to be controlled by the user.

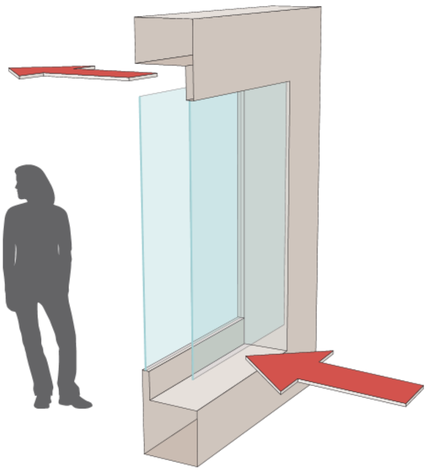

Figure 1. *Perspective view of the dual vented window system*

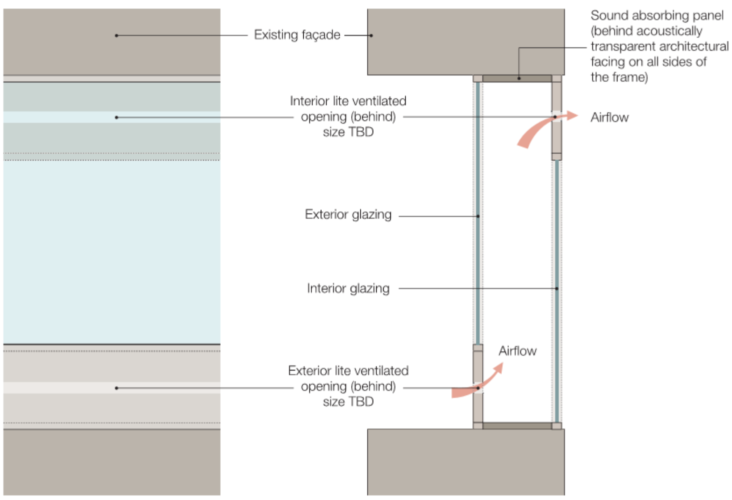

Figure 2. *Section and Elevation view of the dual vented window system*

3. TESTING SET-UP

A partition was constructed in the University of Sydney Acoustic Laboratory between the reverberation room and a main laboratory room (see Figure 3). The wall was constructed with two layers of 13 mm Gyprock Fyrchek plasterboard, bonded together on each side and fixed to timber studs. The wall cavity was filled with Bradford New Generation SoundScreen R2.0 acoustic insulation. All edges were sealed airtight with butyl mastic.

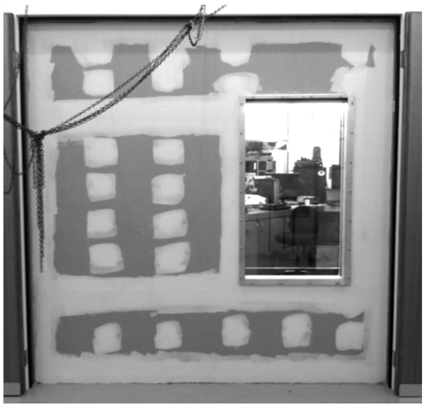

Figure 3. *Test partition in Acoustic Laboratory, University of Sydney.*

A timber window frame was designed to allow for easy and secure replacement of 6.38 mm glass panes to measure various openings sizes. The frame was 1200 mm (height) x 679 mm (width) and 100 mm (depth), mounted off-centre on the partition with recessions for the glass to sit. Aluminium and timber strips secure the glass into the recession and are fastened using butterfly nuts. Foam PVA tape of 5 mm thickness formed a seal between the timber and glass. Acoustically absorptive material consisting of 50 mm thick Tontine Acoustisorb 3 was placed on the inner window frame surfaces for all tests that specify usage of absorptive material (see Figure 4).

Figure 4. *Dual-vented window in the 100 mm ventilation opening configuration and absorptive material fixed to vertical surfaces of the window frame*

4. MEASUREMENT DETAILS

Airborne sound insulation was measured in accordance with ISO 10140-2 [2]. The reverberation room (129.91 m^3) in the laboratory was used as the source room and the main laboratory control room (201.65 m^3) as the receiving room. A pink noise sound source was used in the source room as the test signal for sound insulation measurements.

Sound source equipment list:

- Turbosound TA-500 loudspeaker
- Dolby Lake Processor
- Lab.gruppen amplifier
- Brüel & Kjær Type 1054 Sine/Noise Generator

4.1 Source Room Diffusivity

The spatially averaged sound pressure level in the source room was measured repeatedly throughout the study. These measurements were conducted using a Brüel & Kjær 2250 sound level meter and a Brüel & Kjær 3923 rotating microphone boom. The maximum average variation observed across the measured 1/3-octave bands was +/- 0.2 dB, representing a sufficiently diffuse source room.

4.2 Receiving Room Measurement

The spatially averaged sound pressure level (L_{eq}) was recorded in the receiving room using the sound level meter, handheld at a fixed 2 m distance from the partition. The meter was moved in an angular fashion, similar to the rotating microphone boom, over a 64 second duration. This was repeated consistently for each window configuration. See Table 1 for a list of measured configurations. Absorptive material locations are noted as ‘vertical’ and ‘horizontal’, indicated the window frame/s the material was installed.

The desired minimum signal-to-noise ratio of 10 dB was met in all 1/3-octave bands, except for 4 kHz, 5 kHz and 10 kHz (8.5 dB, 8.7 dB and 9.8 dB respectively), due to the limitations of the available sound source. These measurements were performed with both full panes of glass installed and therefore represented the worst-case scenario. The signal-to-noise ratio exceeded 10 dB in all 1/3-octave bands for dual-vented and closed single-pane configurations.

Table 1: *List of window configurations tested for sound insulation.*

Ventilation Openings	Absorptive Material
Closed (dual panes)	None
Closed (single pane)	None
50 mm	- None - Vertical only - Vertical and Horizontal
100 mm	- None - Vertical only - Vertical and Horizontal
200 mm	- None - Vertical only - Vertical and Horizontal

4.3 Flanking Paths

Sound intensity was measured using a Brüel & Kjær 2260 Investigator with a phase and amplitude-matched pair of Brüel & Kjær 4197 microphones to determine if flanking was compromising the integrity of the results. Eight flanking elements numbered 1 – 8 (see Figure 3) were measured, scanned in the parallel line technique described in ISO 15186-2 [3]. The test window cavity was filled with absorptive material and 6 mm medium density fibreboard sheets were clamped against the glass panes as a second insulating layer to allow for better identification of sound radiating from flanking elements. No measurable flanking paths were identified.

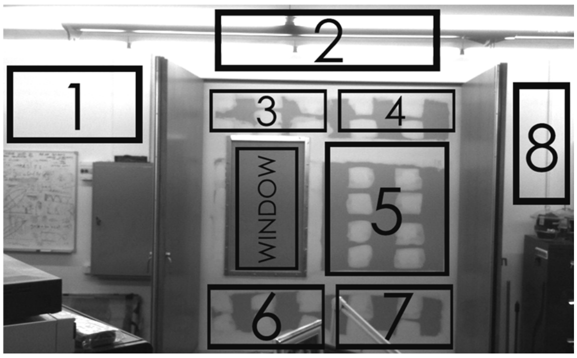

Figure 3. *Area testing for flanking using the sound intensity method.*

4.4 Room Corrections

The reverberation time and volume of the receiving room are factored into Apparent Sound Reduction Index (R') calculations. Substantial measured background noise levels at lower frequencies made it difficult to obtain accurate T_{60} results below 250 Hz, even with more than 55 dB signal-to-noise ratio across all 1/3-octave bands. A remotely controlled HVAC system was considered the main cause of background noise.

Satisfactory results were obtained using a four-microphone Brüel & Kjær PULSE system (interrupted pink noise method). Two loudspeaker and two microphone positions were used. Due to the minimal floor area, a third configuration, while keeping the equipment a minimum 2 m apart and 1.2 m from room surfaces, was not feasible.

Reverberation Time equipment list:

- Meyer MTS-4A loudspeaker
- RME Babyface audio interface
- Brüel & Kjær Type 4190 microphones/Type 2669 preamplifier

Measured one third octave band reverberation times in the receiving room are shown in Figure 5.

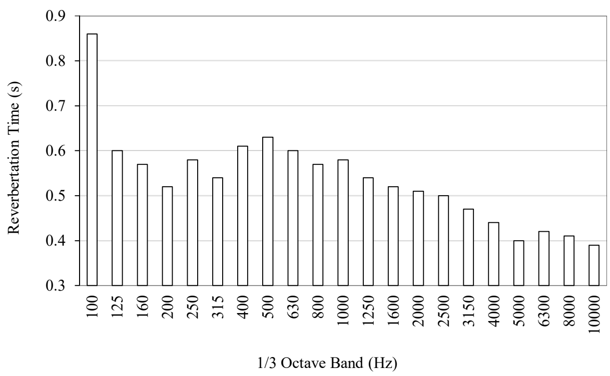

Figure 5. *Reverberation time measurement results in the receiving room.*

5. RESULTS

5.1 Effect of Ventilation Opening Size

The effect of ventilation opening size (without any acoustic material lining installed) on acoustic performance is shown in Figure 6. The results correlate reasonably well above 1.25 kHz, with a general increase in acoustic performance as the ventilation opening size reduces. Results below 500 Hz are less consistent, due to the relatively small ventilation opening sizes compared to wavelength of incident sound.

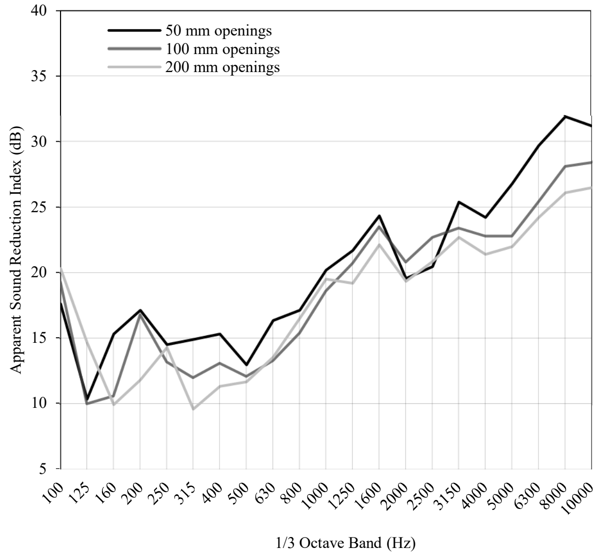

Figure 6. *Comparison of R' results with 50 mm; 100 mm; and 200 mm openings.*

5.2 Absorptive Material

In general, the use of absorptive material on the inner window frame edges resulted in a significant improvement in R' (see Figure 7 for representative results with a ventilation opening of 100 mm). The results indicate that increased acoustic performance is achieved in the mid to high frequency bands, consistent with the published sound absorption coefficients of Tontine Acoustisorb 3 [4].

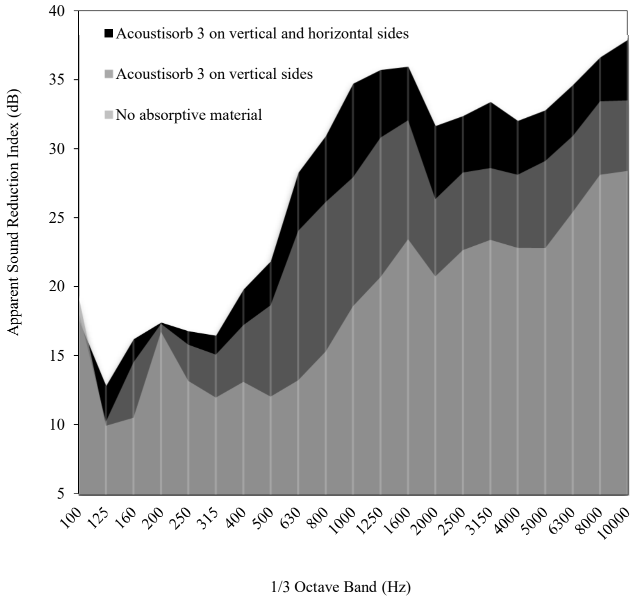

Figure 7. *Comparison of R' for 100 mm openings with and without absorptive material on the inner window frame sides.*

5.3 Ventilation Size and Absorptive Material

The full set of test octave band results for various ventilation opening sizes and amount of acoustically absorptive material added to the inner faces of the window frame are shown in Table 2 below.

Table 2: *Comparison of sound reduction index (R') results for various ventilation opening sizes and amount of acoustically absorptive material added*

		Apparent Sound Reduction Index R'(dB)					
Opening size	**Absorptive Material**	**125 Hz**	**250 Hz**	**500 Hz**	**1 kHz**	**2 kHz**	**4 kHz**
50 mm	Unlined	13	15	15	19	21	25
	Vertical Sides Only	15	17	22	29	27	32
	All Sides	19	22	27	35	36	41
100 mm	Unlined	12	14	13	18	22	23
	Vertical Sides Only	13	16	19	28	28	29
	All Sides	15	17	22	33	33	33
200 mm	Unlined	13	12	12	18	21	22
	Vertical Sides Only	14	14	18	27	26	27
	All Sides	15	14	20	30	28	30

The results indicate that as the **ventilation opening size increases**:

- For the unlined window frame, the acoustic performance in all octave bands only generally decreases by 1-3 dB from 50 mm to 200 mm opening size.
- When acoustic lining is added window frame, the acoustic performance in the low frequency bands (<500 Hz) generally decreases by 3-5 dB from 50 mm to 200 mm opening size.
- When acoustic lining is added window frame, the acoustic performance in the mid to high frequency bands (500 Hz – 4kHz) generally decreases by 3-5 dB.

The results indicate that **when acoustic lining is added** to the window frames compared to the unlined frames:

- The most pronounced improvement in acoustic performance occurs across all octave bands for the smaller ventilation opening sizes because the area of acoustic lining added is large in comparison to the area of the ventilation opening.
- The greatest improvement in acoustic performance occurs in the mid to high frequency bands (up to 16 dB in the 500 Hz – 4kHz bands) where the acoustic absorption coefficient of the acoustic lining is best.

5.4 Weighted Apparent Sound Reduction Index

The weighted apparent sound reduction index (R'_W) for various window opening sizes and acoustically absorptive material configurations is shown in Figure 8. The results indicate that there is a significant improvement in sound insulation performance from the addition of absorptive material to the horizontal window and vertical frame sides as the ventilation opening size becomes smaller. This is due to the larger relative increase in area of absorptive material compared to the ventilation opening area for the smaller openings.

The results indicate that a dual vented window with 50 mm opening, with an acoustic lining applied to the inner surfaces of the window frame, achieves the same R'_W performance as a fully sealed 6.38 mm laminated pane of glass.

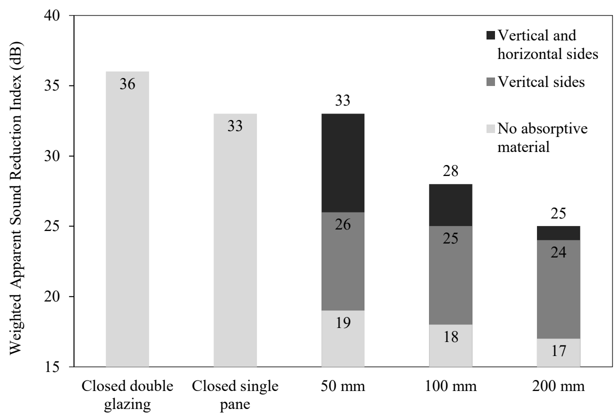

Figure 8. *Comparison of R'_W results for various ventilation opening sizes and absorptive material*

5.3 Airflow Measurements

Airflow through the ventilation openings with and without acoustic material installed was measured to determine the comparative expected increase in pressure drop (or reduced air flow volume) as ventilation size decreased and/or as acoustic material was added to the inner surfaces of the window frame. A remote air handling unit (AHU) servicing the reverberation chamber supplied a constant air supply volume throughout the measurement period, pressurising the room sufficiently to be able to measure pressure drop and airflow at a fixed location close to the ventilation opening in the receiving room. The results are presented in Table 3 below.

Table 3: *Pressure Drop (Pa) and Airflow Measurements (L/s) for the various window configurations*

Ventilation Opening Size	Absorptive Material	Pressure Drop (Pa)	Airflow (L/s)
50 mm	- None - Vertical only - Vertical and Horizontal	9.5 10.3 19.7	56 53 44
100 mm	- None - Vertical only - Vertical and Horizontal	6.0 6.9 10.2	101 96 56
200 mm	- None - Vertical only - Vertical and Horizontal	3.9 4.9 5.3	113 116 110

The results indicate that for the 50 mm ventilation opening size, the pressure drop across the ventilation opening more than doubles when acoustic material is added to all inner faces of the window. As expected, as the ventilation size increases, the increase in pressure drop across the opening is less severe when the acoustic lining is added.

6. DISCUSSION

The results presented above indicate that, as expected, the sound insulation performance of the dual vented window system performs best when the ventilation opening sizes are smallest.

The overall R'w results indicate:

- For an unlined system, the R'_w reduces marginally from 19 to 17 as the ventilation opening size increases from 50 mm to 200 mm.
- With an acoustic lining applied to all the inner surfaces of the window frame, the dual vented window system with 50 mm opening, achieves the same R'_w performance as a fully sealed 6.38 mm laminated pane of glass.
- With an acoustic lining applied to all the inner surfaces of the window frame, the R'_w reduces from 33 to 25 as the ventilation opening size increases from 50 mm to 200 mm.
- With an acoustic lining applied to the vertical inner surfaces of the window frame only, the R'_w reduces marginally from 26 to 24 as the ventilation opening size increases from 50 mm to 200 mm.

It is therefore concluded that the relative area of acoustic lining compared to the ventilation opening area is critical in the sound insulation performance of the window system.

When this is then considered against the pressure drop and airflow measurement results shown in Table 3, the acoustic performance requirements for such a system need to be weighed up against the ventilation requirements. The airflow and acoustic measurements do indicate that this dual vented window system would be feasible in residential applications.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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