

Challenges of using passive ventilation to control the overheating of dwellings in noisy environments

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ABSTRACT

Where residential developments rely on opening windows to control overheating, there can be a compromise between allowing excessive noise ingress with windows open, or excessive temperatures with windows closed. This problem is exacerbated by the move towards better insulated, more airtight buildings and the need, particularly in urban areas, to consider development on noisier sites. A working group has been formed by the Association of Noise Consultants to provide guidance on acoustic conditions and design when considering both the provision of ventilation and prevention of overheating. The guidance produced by the group aims to clarify the relevant definitions of ventilation and overheating, give quantitative guidance as to how to assess internal noise levels and provide examples of acoustic design solutions. This paper discusses the development and contents of the guide and presents practical methods available to provide ventilation which controls overheating and noise levels without the need to introduce mechanical cooling systems. Case studies of projects include passive ventilation systems using attenuated façade vents and methods of using balconies to reduce noise levels incident on open windows.

KEYWORDS

Noise, Overheating, Passive, Ventilation

1 INTRODUCTION

This paper has been produced partly in conjunction with the work undertaken by the Acoustic Ventilation and Overheating group (AVOG), as formed by the Association of Noise Consultants, which is producing the ANC Guide to Acoustics, Ventilation and Overheating in dwellings to support the “ProPG: Professional Practice Guidance on Planning & Noise” (ProPG) (IOA, ANC & CIEH, 2017).

Although problems with overheating are becoming apparent throughout the UK, the highest proportion of residences where overheating is likely are within London, which experiences higher ambient temperatures. The London Plan (GLA, 2016), Policy 5.9, sets out the cooling hierarchy within the sustainability agenda. The London Plan prioritises the requirement to reduce overheating through good building design, before considering passive and mechanical ventilation solutions. This prioritisation mirrors in many ways a good acoustic design approach described in the ProPG where the location, orientation and layout of properties should be considered first to reduce the necessity for façade sound insulation to mitigate any

adverse effects. The priority described in the ProPG is for people to be able to freely open their windows without any adverse effects from external noise ingress.

The practical examples discussed in this paper follow this hierarchy by looking at options for reducing the internal noise impact by considering building location, orientation, internal layouts, façade design, followed by passive ventilation options. Mechanical ventilation and mechanical cooling options are not considered within this paper.

2 ACOUSTIC, VENTILATION AND OVERHEATING GUIDANCE DOCUMENT

The main aim of the Acoustic, Ventilation and Overheating Guidance (AVOG) document is to assist with the façade sound insulation design and assessment of indoor ambient noise levels for dwellings concurrently with the provision of ventilation and consideration of the overheating mitigation strategy.

Traditionally, the provision of façade sound insulation to protect against outdoor sound has been considered separately from the ventilation strategy and any strategy for mitigating overheating. These aspects have all-to-often been considered by different designers making different assumptions; this guide aims to assist designers to adopt an integrated approach to the acoustic design within the context of the ventilation and thermal comfort requirements.

The document aims to provide:

- an explanation of current definitions of ventilation and overheating;
- an indication of potential forms of criteria that could be chosen during the acoustic design; and
- examples of design solutions and case studies.

The guide is intended for the consideration of new residential development that will be exposed predominantly to airborne sound from transport sources, and to sound from mechanical services that are serving the dwelling. The guide seeks to encourage an assessment of noise that recognises the interdependence with the design for ventilation and overheating.

This guide is intended to be used by acousticians in order to:

- provide a means of assessment to satisfy the need to consider acoustics, ventilation and overheating at the planning stage
- provide a framework to inform the design of a residential development
- assist in educating clients, environmental health officers and other stakeholders of the interdependence of design for acoustics, ventilation and overheating

The guide is currently being finalised for review and is expected to be published towards the end of 2017.

3 GOOD ACOUSTIC DESIGN

The priority of ‘good acoustic design’ aims to reduce the need for acoustic façade treatment by considering the building locations and orientation, internal layouts and mitigation for controlling noise at source. An example of ‘good acoustic design’ is a housing development in Swanley, Kent UK.

The proposed residential development site is affected by noise from an adjacent paper mill, as well as road and rail traffic noise. The guiding principles of ‘good acoustic design’ were prioritised by the design team; this inspired the massing of site layout, the internal dwelling layouts, and the holistic approach to achieving good internal environmental quality, which were essential to achieving planning permission.

The design team then developed a series of measures which were incorporated into the site proposals including:

- Apartment blocks adjacent to the paper mill, forming a noise barrier to shield the rest of the development and achieve reasonable external amenity area noise levels to proposed houses.
- Layout of apartments arranged so that no windows of habitable rooms face towards the paper mill.
- All apartment block balconies located on the opposite side from the paper mill.
- Building envelope and ventilation strategy developed to achieve paper mill noise levels within apartments to be significantly below guideline values from Table 4 of BS 8233.
- Noise barriers at the boundary of the site to control propagation of rail noise.
- Holistic approach to noise, ventilation provision and controlling overheating across the site.

The site layout can be seen in Figure 1 and the internal building layout and window locations can be seen in Figure 2. The resultant scheme was granted planning permission with no objections regarding noise from the paper mill, their acoustic consultant, or the local planning authority. It demonstrates how the design of the buildings can enable passive ventilation, and maximise the use of openable windows, on sites which have previously been considered as being too noisy.

For some developments, ‘good acoustic design’ may not suitably control noise levels across a site and other mitigation options must be provided to enable passive ventilation strategies for controlling overheating.



Figure 1: Site layout

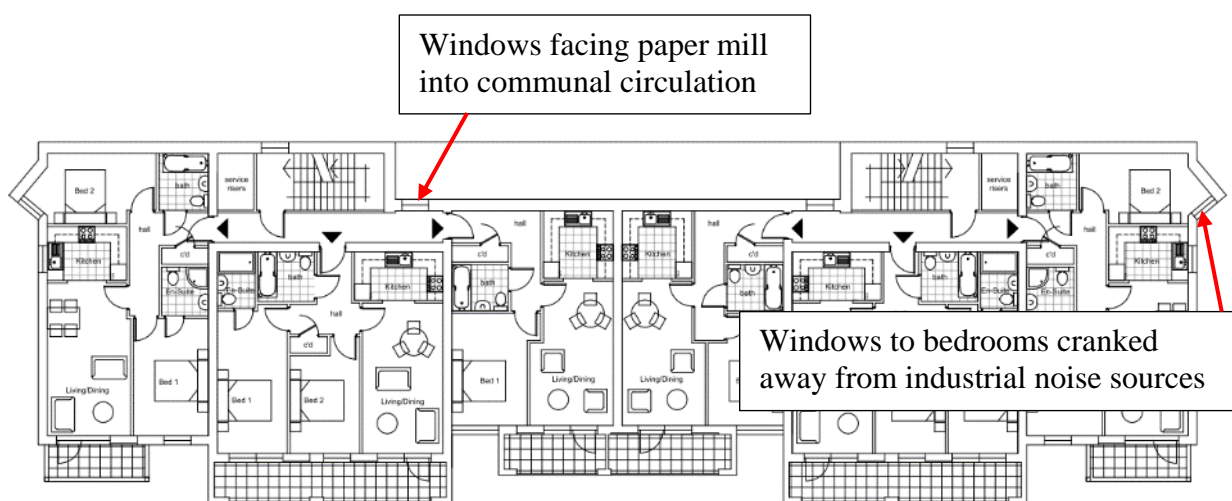


Figure 2: Internal layout and window locations

4 BALCONIES

Balconies can be used to reduce the noise levels at passive ventilation openings and this is supported in the draft ProPG which includes the statement:

“Where balconies are required, solid balustrades with sound absorption material added to the underside of balconies above is a good means of reducing noise entering the building.”

BS EN 12354-3 (BSI, 2000) provides a method for predicting the internal noise levels of buildings with various external façade shapes. It gives different façade shape level differences ΔL_{fs} ; which is defined such that ΔL_{fs} is 0 for a plane façade; and these values range from -1 for a shallow balcony with no parapet or absorption, up to 4 dB for a balcony with a solid parapet and absorptive soffit.

Naish & Tan (Naish & Tan, 2007) concisely summarised the research up to 2007 in their ICSV14 paper ‘A review of residential balconies with road traffic noise’ which describes different studies based on in-situ measurements, the use of scale models and numerical modelling techniques. They found that several studies (Gustafsson, 1973) (May, 1979) (Tzekakis, 1983), measured reductions in internal noise levels of 4 to 5 dB for balconies which had solid parapets and absorptive soffits, consistent with the values indicated in EN12354. Further studies (Hammad, 1983) (Lee, 2007) looked in more detail at increasing the absorption within the balcony and reducing the open area. These included scenarios which could provide up to 10 dB reduction compared to a plane façade.

More recently at Internoise 2016, Yeung presented (Yeung, 2016) in-situ measurements for balconies which varied from 5 dB reductions for modifications to the parapet and absorption to the balcony, up to a 17 dB reduction which was provided by a window arrangement which had the opening below the top of the parapet, and included absorptive linings to the parapet inner face.

At the same conference, Leung presented (Leung, 2016) findings from in-situ tests of a complete mock up. These included a scenario shown in Figure 3 where the balcony had an outer screen, and the inner façade had a door opening, with the purpose of providing natural ventilation. The balcony included absorptive finishes and the measurements found that a 10 dB improvement could be achieved, compared to a plane façade with the same opening size.

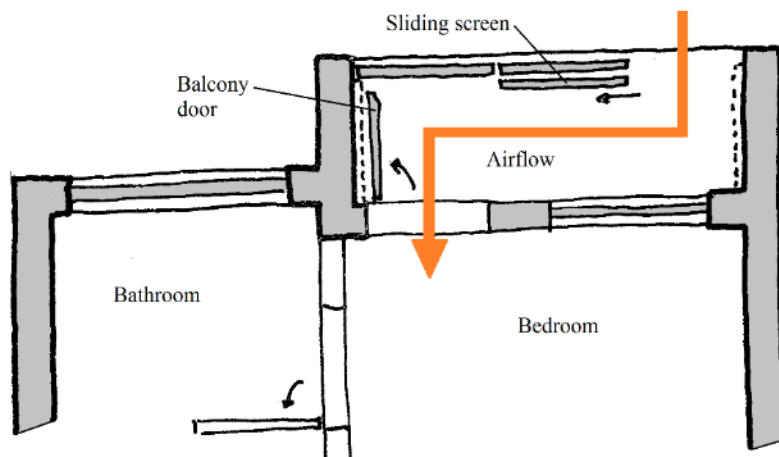


Figure 3: Section showing balcony arrangement

Although absorption to the underside of balconies is not a common solution in the UK there are examples of its approach within planning applications (AECOM, 2015) and there are some commercially available products as shown in Figure 4.



Figure 4: Absorptive lining to the underside of a balcony

5 PASSIVE VENTILATION OPTIONS

5.1 Ventilation rates to control overheating

The ventilation rates to control overheating are generally much greater than the ventilation rates required to meet the whole house indoor air quality requirements, and they can reach the rates associated with purge ventilation.

We find that typically 2 air changes per hour are required for controlling overheating which can require a façade equivalent open area of at least $1/40^{\text{th}}$ of the floor area of the room, so for example a bedroom with a floor area of 8m^2 would require a facade opening of 0.2m^2 , which is approximately 4% of the façade area for that room.

5.2 Standard Windows

Opening windows are typically claimed to achieve a level difference of “10 – 15 dB” (WHO, 1999) between outside and inside. For the example bedroom described above, a 0.2m^2 open area would provide a predicted reduction of 11 dB from external free field levels to the internal levels.

In practice, the attenuation achieved will depend on a variety of factors, and the extensive testing carried out at Napier University (Napier, 2007) illustrates the variation in level and frequency that may be found for different window types open to different extents. The size of and absorption in the room will also influence the in-situ level differences achieved by opening windows.

The Napier study suggests improvement of 2-3 dB may be achievable if the type of window hinging and opening arrangements are optimised, however, in many situations opening windows do not provide sufficient attenuation of external noise ingress and further attenuation is required.

5.3 Attenuated Windows

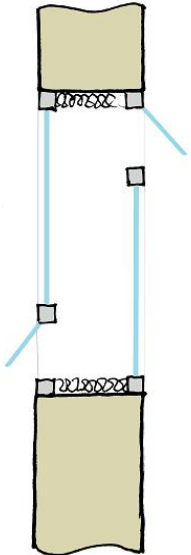
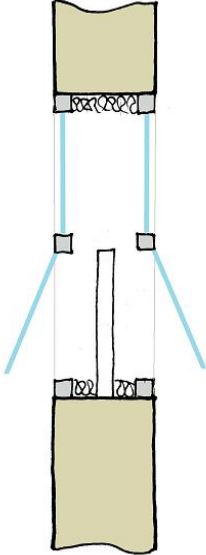
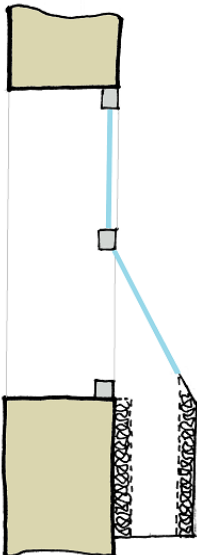
The authors are not aware of any project where enhanced acoustic performance from modified openable windows have been used for residential projects in the UK. Some performance data and options are included within a Danish study (Søndergaard, 2016) which was undertaken because of the need to provide openable windows in dwellings (0.35 m² open area), and the understanding that this limited land suitability for housing where the noise levels were too high.

The study includes three sets of measurements and is based on three different approaches:

- Dual glazing with top and bottom hung openings, not aligned, and absorptive linings between the glazing.
- Dual glazing with side hung windows which include a sliding barrier to remove the direct path from outside to inside.
- An externally mounted attenuator connected to the openable window.

The arrangement of the windows and summary of the test results are shown in Table 1. The paper includes a very comprehensive arrangement of tests, although it isn't clear what the measurement area is for establishing the sound reduction index, R_w values. For vents, including open windows, $D_{n,e,w}$ (C; C_{tr}) values would be more appropriate for undertaking noise ingress calculations.

Table 1: Glazing arrangement and test results

		
<p>The measured R_w values ranged from 16 dB without absorption up to 30 dB with absorption to the reveals and cavity side of the window openings</p>	<p>The measured R_w values ranged from 7 dB with no central barrier up to 23 dB for a barrier the same width as the window opening and absorption to the reveals</p>	<p>The external attenuator provided an R_w of up to 21dB and in practice the length of the unit could be adjusted to provide higher values if required.</p>

Based on the measured performance, it would seem possible to use attenuated window systems where a reduction of 20 dB was required for external to internal levels, while providing ventilation rates which could help control overheating.

5.4 Attenuated vents

The following case studies for attenuated vents include large façade openings, with attenuation, to allow passive ventilation with reduced noise ingress compared to open windows.

5.4.1 Case Study 1 - North West Cambridge, Lots 3 and 5

The North West Cambridge Development includes up to 1,500 affordable homes for University and College staff, 1,500 private homes and accommodation for 2,000 postgraduates. The scheme is separated in several different 'Lots' each with a different architect and a range of main contractors.

The site is exposed to motorway noise from the M11 and noise from the local traffic within the development. A sustainability statement for the development expressed a desire for natural ventilation for the University accommodation which meant that bespoke designs had to be developed to meet the acoustic and thermal insulation performance requirements for the façades, while allowing overheating to be controlled without a mechanical system.

The external façade levels were predicted based on traffic data and baseline measurements of the motorway noise levels. Maximum levels were not assessed for this project as the dominant source was steady noise from the motorway. A planning condition from the outline planning approval required good indoor ambient noise levels in living rooms and bedrooms when the spaces were being rapidly ventilated.

The building physics modelling established the ventilation rates required to control overheating and these were up to two air changes per hour which is considerably higher than the rates normally achieved with domestic MVHR units. To achieve two air changes per hour through a façade ventilator the open area for typical bedrooms was 0.2 m².

For night-time periods a limit of 35 dB $L_{Aeq,8hr}$ in bedrooms was required. Noise ingress calculations were undertaken for a 0.2 m² façade opening and an external upper level of 48 dB $L_{Aeq,8hr}$ was used to establish the bedrooms which could be ventilated with openable windows to control overheating. For the façades which were predicted to be exposed to noise levels greater than these attenuated vents were used to provide sufficient air changes to control overheating. Further details of the project can be found in the planning documents submitted with the reserved matters applications (URS, 2013)

The external noise level at the site were up to 67 dB $L_{Aeq,16hr}$ during the daytime and 62 dB $L_{Aeq,8hr}$ during the night-time. These therefore required attenuation which could reduce the free field external levels by more than 27 dB.

A section through the façade of Lot 3 can be seen in Figure 5, and the external facades can be seen in Figure 6 and Figure 7. An internal view of the rooms in Figure 8 shows the attenuated vent opening adjacent to the windows.

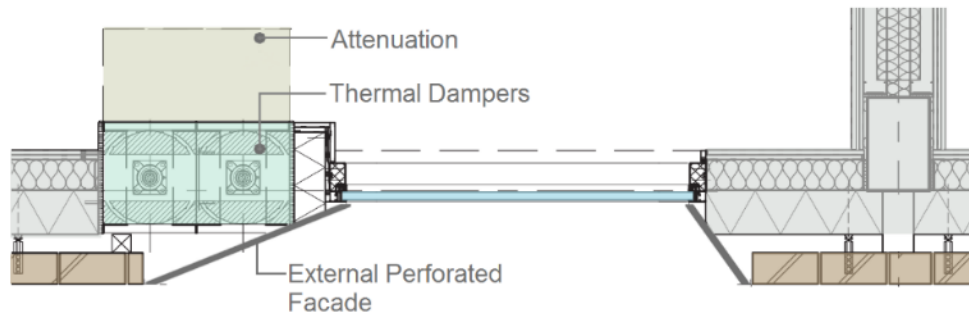


Figure 5: Lot 3 Section through the facade



Figure 6: Lot 3 façade showing perforated panels to window reveals



Figure 7: Lot 5 façade showing perforated panels adjacent to windows



Figure 8: Internal view of attenuated vent opening adjacent to the windows

5.4.2 Case Study 2 - Clapham, London

The scheme is a large residential development alongside a busy railway line in London. The site is also affected by road traffic noise. This case study considers a typical bedroom located on the façade facing the railway at 1st floor level (i.e. that which is most affected by railway noise).

There were potential significant adverse effects due to noise ingress if open windows were used to control overheating, so criteria were developed to enable attenuated vents to be specified for the bedrooms overlooking the railway. The development overheating was assessed with the CIBSE Guide A (CIBSE, 2006). The façade to the bedroom being assessed faces W/NW. Solar control glass was used to limit solar gains and relief of overheating is achieved by using a passive façade ventilator, referred to as the ‘louvered acoustic vent’.

The external noise levels at the façade of the bedroom being assessed have been determined from on-site measurements as 66 dB $L_{Aeq,8hr}$ and the internal noise level requirements during ventilation to control overheating were 40 dB $L_{Aeq,8hr}$. Therefore, a sound reduction of more than 26 dB was required through the attenuated vents.

The louvered acoustic vent was designed to provide a face area of around 1 m² and a ventilation free area of around 0.4 m². It was anticipated that, in order to achieve comfortable internal temperatures, the louvered acoustic vent will need to be open for around 10-15% of the time (over the course of a year) depending on the occupants’ behaviour. The arrangement of the vents within the room and external and internal images of the attenuated vents are shown in Figure 9 and Figure 10.

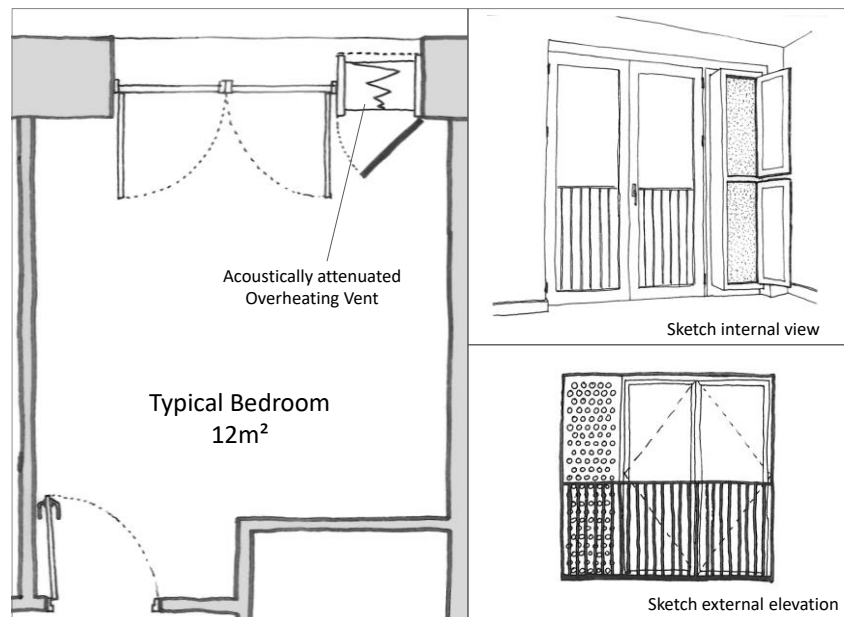


Figure 9: Clapham case study room arrangement

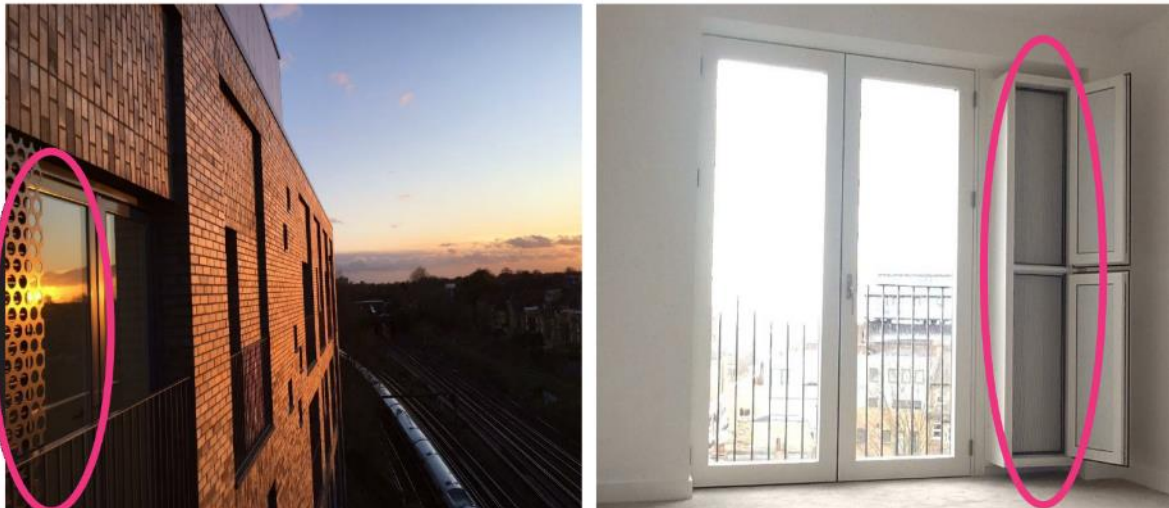


Figure 10: Clapham case study external and internal views

6 CONCLUSIONS

Following the principles of ‘good acoustic design’ can increase the number of habitable residential rooms which can be ventilated with openable windows. This considers the locations, orientation and layout of buildings to reduce the noise levels incident on the façades of habitable rooms.

The use of balconies can reduce noise levels incident at ventilation openings, and these can provide an additional 5 dB improvement compared to designs without balconies. If the balconies are partially enclosed this can increase to 10 dB improvement, with suitable treatments to the balconies.

Attenuated windows are not common in UK designs, but they have the potential to provide 10 dB improvement compared to a simple opening window. Consideration of the window hinging and opening arrangements can provide 2-3 dB improvement for some noise sources.

Attenuated openings to provide ventilation rates to control overheating have been used on two separate case study projects in the UK. These are providing attenuation up to 27 dB from external free-field to internal levels, while providing the ventilative cooling rates required to control overheating.

7 ACKNOWLEDGEMENTS

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8 REFERENCES

- AECOM (2015) *North West Cambridge LotM1/M2 Reserved Matters Noise Insulation Scheme*, Online reserved matters application, Cambridge City Council reference 15/1663/REM
- Institute of Acoustics, Association of Noise Consultants and Chartered Institute of Environmental Health, (2017) *ProPG: Professional Practice Guidance on Planning & Noise*, Draft
- The Greater London Authority (2016), *The London Plan - The spatial development strategy for London consolidated*.
- Chartered Institution of Building Services Engineers (2006), *Environmental Design: CIBSE Guide A*, 6th Edition.
- British Standards Institute (2000), EN 12354-3:2000 Building acoustics. Estimation of acoustic performance in buildings from the performance of elements. Airborne sound insulation against outdoor sound, *British Standards Institute*, London.
- Naish, D. and Tan, A. (2007), A review of residential balconies with road traffic noise, *Proceedings of 14th International Congress on Sound and Vibration, ICSV14*, Cairns, Australia, 9-12 July
- Gustafsson, J.-I. and Einarsson, S. (1973), Gallery houses with respect to traffic noise, *Proceedings of Inter-noise 73*.
- May, D.N. (1979), Freeway noise and high-rise balcony, *Journal of Acoustical Society of America* 65, 699-704
- Tzekakis, E.G. (1983), On the noise reducing properties of balconies, *Acustica* 52, 117-21
- Hammad, R.N.S. and Gibbs, B.M. (1983), The acoustic performance of building facades in hot climates: Part 2--Closed balconies, *Applied Acoustics* 16, 441-454
- Lee, P.J., Kim, Y.H, Jeon, J.Y. and Song K.D. (2007), Effects of apartment building façade and balcony design on the reduction of exterior noise, *Building and Environment* 42 (10, 3517-3528)

- Yeung, M. (2016), Adopting specially designed balconies to achieve substantial noise reduction for residential buildings”, *Proceedings of Inter Noise*, 1185-1190
- Leung, J. and Chu, M.W. (2016), Research and development of noise mitigation measures for public housing development in Hong Kong – A case study of Acoustic Balcony, *Proceedings of InterNoise*, 1199-1207
- Napier University (2007), NANR116: Open /Closed window research - Sound Insulation through ventilated domestic windows. *School of the Built Environment*, Technical report, Napier University.
- URS (2013) *North West Cambridge – Lot 5 Reserved Matters Application Noise Insulation Scheme*, Cambridge City Council, Planning application Ref: 13/1827/REM
- URS (2013) *North West Cambridge – Lot 3 Reserved Matters Application Noise Insulation Scheme*, Cambridge City Council, Planning Application Ref 13/1400/REM
- Søndergaard, L.S. and R Egedal, R. (2016), Open windows with better sound insulation, *Proceedings of Inter-Noise*, Hamburg, 1173-1184
- World Health Organisation, (1999), *Guidelines for community noise*, World Health Organisation, Geneva.