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METHODS OF CONTROLLING NOISE LEVELS AND OVERHEATING IN RESIDENTIAL BUILDINGS

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The need to mitigate overheating in modern dwellings requires ventilation rates much greater than those provided by whole house ventilation systems which simply comply with Part F of the Building Regulations. The provision for purge ventilation, usually opening windows, is typically relied upon for this purpose. However, high noise levels are frequently cited as a reason that residents are reluctant to open windows to provide increased ventilation, and they may suffer from overheating as a result. This paper presents practical methods to provide ventilation rates for overheating mitigation with enhanced levels of façade sound insulation compared with open windows. A brief review of solutions considered in the literature is presented first, which include methods of using balconies to reduce noise levels incident on windows, and novel arrangements of window opening lights to achieve higher levels of sound insulation. Five UK case studies are presented that include passive ventilation systems using attenuated façade vents and mechanical systems with increased ventilation rates.

Keywords: overheating, noise, ventilation, residential façade sound insulation,

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 [1] to support the "ProPG: Professional Practice Guidance on Planning & Noise" (ProPG) [2]. The AVOG guidelines will 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.

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 [3], Policy 5.9, relates to overheating and cooling and it intends to reduce the impact of the urban heat island effect in London and encourages the design of places and spaces to avoid overheating and excessive heat generation. It states that:

Major development proposals should reduce potential overheating and reliance on air conditioning systems and demonstrate this in accordance with the following cooling hierarchy:

1 minimise internal heat generation through energy efficient design
2 reduce the amount of heat entering a building in summer through orientation, shading, albedo, fenestration, insulation and green roofs and walls
3 manage the heat within the building through exposed internal thermal mass and high ceilings
4 passive ventilation
5 mechanical ventilation
6 active cooling systems (ensuring they are the lowest carbon options).

Major development proposals should demonstrate how the design, materials, construction and operation of the development would minimise overheating and also meet its cooling needs.

It is worth noting that the top three aims are broadly addressed by the design of the building fabric, and the bottom three by servicing the building. 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 noise.

The practical examples discussed in this paper also follow this hierarchy by looking at options for reducing the internal noise impact by considering building façade design, followed by passive ventilation options and then mechanical ventilation options. Good acoustic design also encompasses measures to reduce the noise at source, barriers, site layout and orientation of buildings amongst other means, but those are not considered here.

2. Building façade design

The draft ProPG guidance 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 [4] 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 concisely summarised the research up to 2007 in their ICSV14 paper ‘A review of residential balconies with road traffic noise’ [5] which describes different studies based on in-situ measurements, the use of scale models and numerical modelling techniques. They found that several studies [6,7,8] 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 [9,10] 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 Internoise2016, Yeung presented [11] 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 [12] findings from in-situ tests of a complete mock up. These included a scenario shown in **Figure 1** 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.

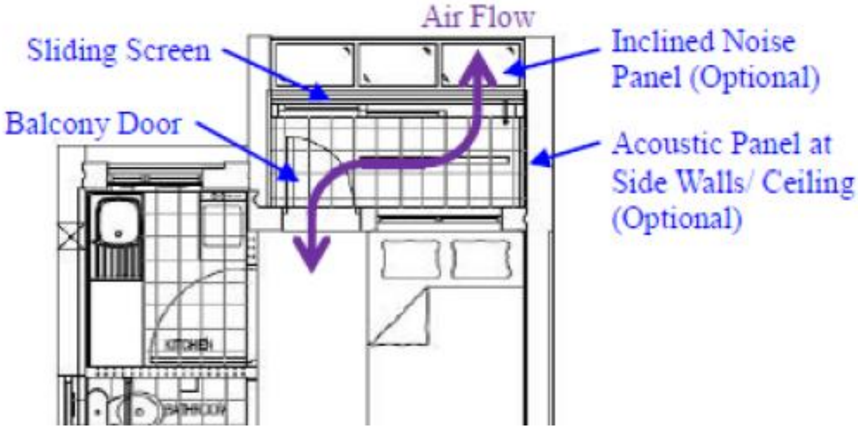


Figure 1: Plan view of balcony arrangement

3. Passive ventilation options

Opening windows are typically claimed to achieve a level difference of "10 – 15 dB" [13] between outside and inside. In practice the attenuation achieved will depend on a variety of factors, and the extensive testing carried out at Napier [14] 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 have an effect on the in-situ level differences achieved by opening windows. However, in many situations opening windows do not provide sufficient attenuation of external noise ingress.

Passive ventilation options for higher noise environments include attenuated vents and windows which are designed to provide enhanced sound insulation when open. All the case studies include some dwellings which have noise levels suitable for openable windows; where predicted noise levels are too high, the alternatives to openable windows are used.

3.1 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.

3.1.1 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 facades, 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. Although the outline condition lacked some definition, through discussions with the local authority the design team agreed a strategy suitable for meeting the local authority requirements.

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 m^2. It was agreed with the local authority that façades exposed to 55 dBA during the daytime could be ventilated with openable windows, irrespective of the predicted levels, as these would have fallen into NEC category A from PPG 24 [15].

For night-time periods a level of 35 dB $L_{Aeq,8hr}$ in bedrooms, noise ingress calculations were undertaken for a 0.2 m^2 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. Therefore, 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 [16;17]

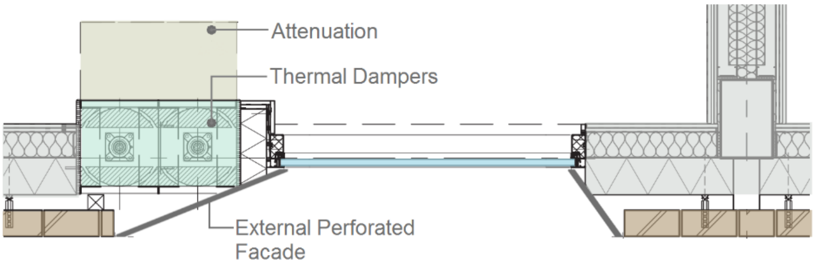


Figure 2: Lot 3 Section through the facade

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

Figure 4: Lot 5 façade showing perforated panels adjacent to windows

3.1.2 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). The external noise levels at the façade of the bedroom being assessed have been determined from on-site measurements.

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 2006 standard. 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 louvered acoustic vent is designed to provide a face area of around 1 m^2 and a ventilation free area of around 0.4 m^2. 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. Given that the overheating situation occurs for only a portion of the year and the louvered acoustic vent is under the occupants' control, it is concluded that the risk of adverse effect on occupants was acceptable.

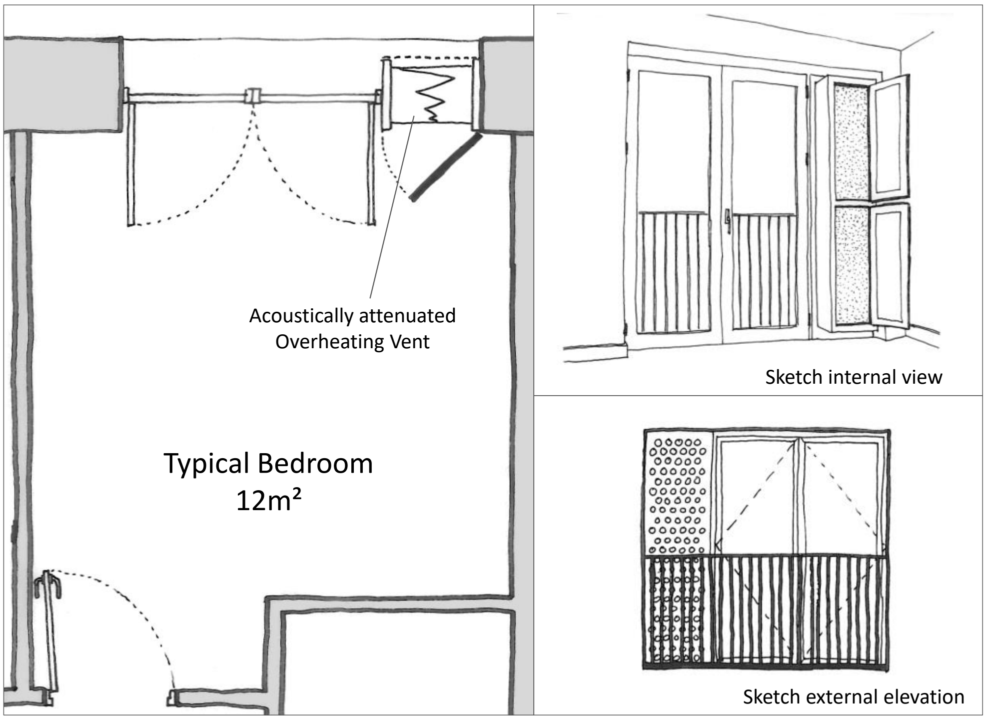


Figure 5: Clapham

3.2 Windows with enhanced acoustic performance

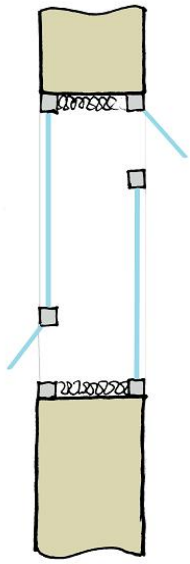
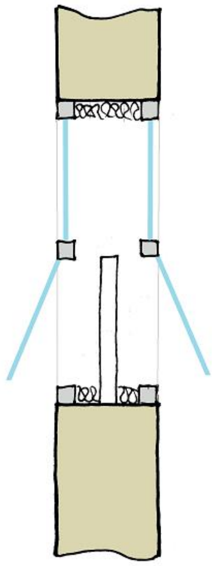
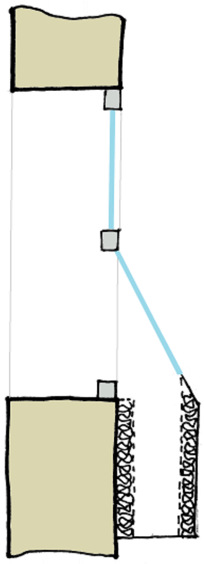
The authors are not aware of any project where enhanced acoustic performance from modified openable windows have been used for residential projects in the UK. Some performance data and options are included within a Danish study [18] which was undertaken because of the need to provide openable windows in dwellings (0.35 m^2 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 summary of test results

		
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	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	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.

4. Mechanical ventilation solutions

Mechanical solutions include supply and extract systems which simply provide sufficient air changes using external ambient air, to control the overheating, and systems which include some form of cooling and therefore need additional external heat exchangers or condensers.

4.1 Mechanical supply and extract

4.1.1 Case Study 3 - North West Cambridge, Lot 8

This case study is based on Lot 8 within the North West Cambridge Development, which includes a medium sized, five story block of 2 bed apartments. This case study considers a typical 3rd floor apartment located on a façade which is exposed to both motorway noise and local traffic noise from the new development. The external façade levels were predicted, based on traffic data and baseline measurements of the motorway noise levels and the free field levels for the most exposed façades the predicted levels were 64 dB $L_{Aeq,16hr}$ during the daytime, and 59 dB $L_{Aeq,8hr}$ during the night time.

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. As with Case Study 1, through discussions with the local authority the design team agreed a strategy suitable for meeting the local authority requirements. For whole house ventilation rates, in accordance with Part F the noise limits are shown in Table 2.

It was advised that to control overheating to meet CIBSE Guide A 2006 criteria the mechanical system would need to provide two air changes per hour for bedrooms and four air changes per hour for living rooms. This would mitigate the need to open windows to control overheating, although the windows can be opened to allow occupant control. Separate fans were proposed for the living room and the bedroom, which brings ambient air into the rooms. The air is extracted through the apartment trickle vents, extract openings in kitchens or bathrooms or through windows which can be opened on the quieter façade. Further details can be found within the planning documents [19]

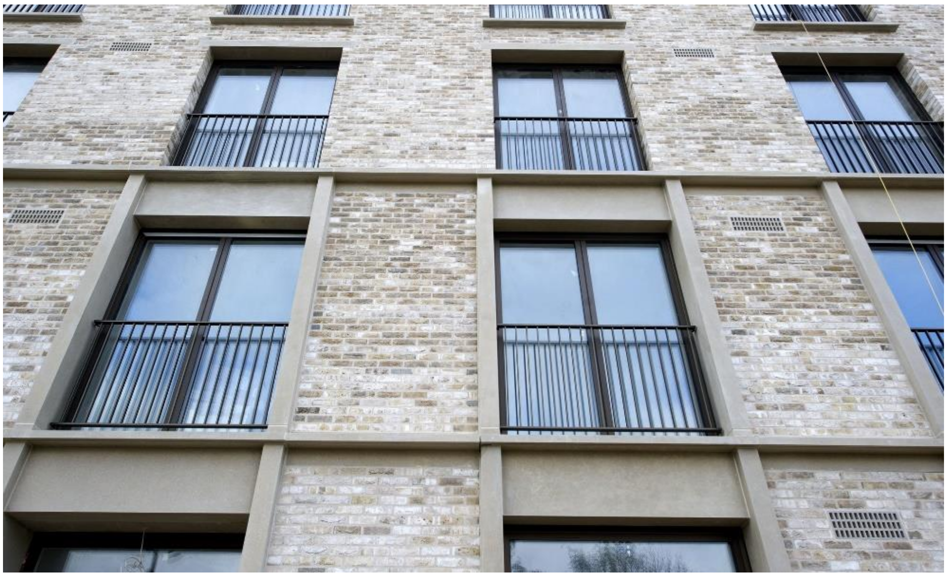


Figure 6: Lot 8

4.1.2 Case Study 4 -15-29 Broadway, Crawley

This development in Crawley has been submitted for planning [20], CR/2015/0609/FUL, and consists of 10 studios, 55 one bedroom flats and 13 two bedroom flats. The planning submission includes an overheating assessment and a noise assessment with subsequent amendments. The noise assessment for the scheme measured external levels of 62 dB $L_{Aeq,16hr}$ during the daytime, and 55 dB $L_{Aeq,8hr}$ during the night time.

The trickle vents and glazing were specified to achieve typical internal noise levels as shown in Table 2. The overheating assessment concludes that the external noise levels are too high for openable windows to control overheating, and that a mechanical system providing 2.2 air changes per hour would be required, in conjunction with blinds fitted to the windows. This was based on an assessment according to CIBSE TM 52.

4.2 Mechanical ventilation with cooling

4.2.1 Case Study 5 - Mixed development in Birmingham

Case study 5 is a development where some dwellings had comfort cooling and some relied on open windows to control overheating, based on the predicted external noise levels. The trickle vents to comply with System 1 of Part F whole house ventilation and glazing were specified to achieve the levels indicated in Table 2. When establishing acceptable noise levels when windows are open for controlling overheating, it was considered that the reasonable levels from BS 8233 could be exceeded by 3 dB for ventilation by open windows. With ventilation rates to control overheating the indoor ambient noise limits in Table 2 were adopted. A reduction of 15 dB was assumed from external levels to internal levels with partially open windows. Therefore, the external levels at which openable windows could be used for controlling overheating where the predicted free field levels were less than or equal to 58 dB $L_{Aeq,16hr}$ during the daytime and 53 dB $L_{Aeq,8hr}$ for the night-time. Where the external levels exceeded these values, mechanical cooling was provided to control overheating.

5. Summary of levels from Case Studies

A summary the various noise limits used in the case studies in provided in **Table 2**. It should be noted that these may been derived from client requirements and appropriate limits for each specific project should be developed following ProPG: Planning and Noise, local authority requirements and the AVOG guide.

Table 2: Summary of noise limits from the case studies

Scenario	External limits for openable windows (free field)					Internal limits for Part F whole house ventilation rates					Internal limits with ventilation rates to control overheating				
Case Study	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Daytime $L_{Aeq,16hr}$	55	-	55	-	58	35	35	35	35	35	40	42	35	-	43
Night-time $L_{Aeq,8hr}$	48	-	48	-	53	30	30	30	30	30	35	37	30	-	38

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REFERENCES

1 ANC Guide to Acoustics, Ventilation and Overheating in dwellings. Due for publishing 2017

2 ProPG: Professional Practice Guidance on Planning & Noise, Draft 2016

3 The London Plan 2016 – The spatial development strategy for London consolidated.[Online]

4 EN 12354-3:2000 Building acoustics. Estimation of acoustic performance in buildings from the performance of elements. Airborne sound insulation against outdoor sound

5 D Naish and A Tan, A review of residential balconies with road traffic noise, *Proceedings of 14th International Congress on Sound and Vibration*, ICSV14, Cairns, Australia, 9-12 July 2007

6 J.-I. Gustafsson and S. Einarsson, "Gallery houses with respect to traffic noise," Inter-noise 73.

7 D. N. May, Freeway noise and high-rise balcony, *JASA 65*, 699-704 (1979)

8 E. G. Tzekakis, On the noise reducing properties of balconies, *Acustica 52*, 117-21 (1983).

9 R. N. S. Hammad and B. M. Gibbs, The acoustic performance of building facades in hot climates: Part 2--Closed balconies, *Applied Acoustics 16*, 441-454 (1983).

10 P. J. Lee, Y. H. Kim, J. Y. Jeon, and K. D. Song, "Effects of apartment building façade and balcony design on the reduction of exterior noise", Building and Environment

11 M Yeung, Adopting specially designed balconies to achieve substantial noise reduction for residential buildings”, Proceedings of Inter Noise 2016, 1185-1190

12 J HL HO and W M CHU “Research and development of noise mitigation measures for public housing development in Hong Kong – A case study of Acoustic Balcony”, InterNoise 2016, 1199-1207

13 Berglund et al, Guidelines for Community Noise, World Health Organisation 1999

14 NANR116: ‘Open /Closed window research’ Sound Insulation through ventilated domestic windows. School of the Built Environment, Napier University 2007

15 Planning Policy Guidance 24: Planning and Noise (PPG24)

16 Cambridge City Council, Planning application Ref: 13/1827/REM

17 Cambridge City Council, Planning Application Ref 13/1400/REM

18 L S Søndergaard and R Egedal. ‘Open windows with better sound insulation’ Proceedings of Inter-Noise, Hamburg 2016 1173-1184

19 Cambridge City Council, Planning application Ref: 14/0109/REM

20 Crawley Borough Council, Planning Application Ref CR/2015/0609/FUL