Assessing noise and overheating in dwellings: aligning acoustic and thermal models for partially open windows

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Abstract

Approved Document O 'Overheating' (England) introduces noise limits for the use of open windows in bedrooms at night. A clarification to the guidance indicates that windows may be modelled as partially open; this enables justification of natural ventilation at night in noisier locations than if windows must be modelled as fully open.

The ventilation performance of open windows may be described in the thermal model by "Equivalent Area" (EA). A simple acoustic model for a partially open window is proposed, based on the Acoustic Open Area (AcOA). However, the use of the EA for the calculation of façade sound insulation provides a consistent understanding between acoustic and thermal modellers. Field measurements suggest no increase in uncertainty when using EA rather than AcOA.

Keywords: Noise, Overheating, Windows, Thermal comfort

1.0 Introduction

The English government has introduced a new Building Regulation (1) to mitigate overheating in new residential buildings. Approved Document O (ADO) (2) provides guidance on the Regulation. When the Regulation came into force in June 2022, the government published a series of FAQs on its website (3) (ADO-FAQ). These ADO-FAQs modify the guidance given in ADO in materially significant ways.

ADO describes how windows cannot be assumed to be open during the night-time period if internal noise levels exceed guideline values. This means that an acoustic assessment and an overheating assessment are both required to assess the indoor environmental quality (IEQ) conditions simultaneously. It is (surprisingly!) challenging to align assumptions regarding acoustic models and thermal models of a partially open window. This paper proposes a new solution to this problem, to facilitate the discussion between building acoustic and thermal modellers.

2.0 Background

2.1 Open area terminology

Jones *et al* (4) provide a set of descriptions that can be used unambiguously to describe façade openings for ventilation performance. "Free area" remains an ambiguous term without consistent definition, despite its widespread use. For example, six different methods of attributing a value of "free area" to an open window are presented by Sharpe *et al* (5) The Equivalent Area (EA) is a description of flow performance that is used in ADO. It is the area of a circular hole in an orifice plate that passes the same volumetric air flow as the element or flow device in question, for the same pressure difference – hence the name, *Equivalent*. Appendix D of ADO refers to an Excel tool to calculate EA (6).

2.2 ADO Simplified Method

The Simplified Method describes requirements for what it describes as a “minimum free area”. However, there is considerable confusion over the use of the term “minimum free area” within ADO, such as para. 1.12:

Openings should be designed to achieve the free areas in paragraphs 1.10 and 1.11 [of ADO]. The equivalent area of the opening should meet or exceed the free area of the opening.

The intended meaning is only confirmed in the ADO-FAQs # 8 [4], which clarifies that everywhere ADO says “minimum free area”, the reader can understand this to mean “minimum equivalent area”.

2.3 Dynamic thermal modelling

If the Simplified Method cannot be used, then compliance must be demonstrated using dynamic thermal modelling. ADO refers to CIBSE TM59 (7) but adds additional constraints to how that methodology is applied. ADO indicates that:

All of the following limits on CIBSE’s TM59, section 3.3, apply:

- *At night (11pm to 8am), openings should be modelled as fully open if … the following apply…*

However, the guidance of ADO-FAQ #14 supersedes the guidance in ADO, by indicating that a strategy relying on:

..opening windows a smaller amount at night…

is permissible.

This note may facilitate demonstration of compliance with ADO by using natural ventilation, as partially open windows provide greater sound insulation, and may thereby meet the noise criteria when fully open windows would fail.

2.4 Acoustic constraints

One of the requirements indicated in ADO for the “reasonable enjoyment of the residence” concerns noise levels. ADO indicates that:

… the overheating mitigation strategy should take account of the likelihood that windows will be closed during sleeping hours (11pm to 7am).
Windows are likely to be closed during sleeping hours if noise within bedrooms exceeds the following limits.

a. 40 dB $L_{Aeq,T}$, averaged over 8 hours (between 11pm and 7am).
b. 55 dB L_{AFmax}, more than 10 times a night (between 11pm and 7am).

3.0 Sound insulation of façade openings

In order to determine the internal noise levels from external sources it is necessary to determine the façade sound insulation provided by a partially open window. For many practitioners, the "10 – 15 dB" quoted by the WHO Guidelines for Community Noise (GCN) (8) is the answer to this question. This rule of thumb takes no account of the extent of window opening, or any of the other factors that may affect the façade level difference. There are four methods for assessing the sound insulation of a partially open window that are considered:

- Theoretical assessment
- Laboratory measurement
- Field measurement with a loudspeaker sound source
- Field measurement with road traffic as a sound source

Each of these approaches is discussed below.

3.1 Theoretical assessment of façade sound insulation

The sound insulation of a building façade against outdoor sound can be calculated according to BS EN ISO 12354-3 (9). The informative Annex D of that Standard suggests that for small openings, a global indication is given by treating the element as an opening with negligible sound reduction. This results in an element normalized level difference as shown in Eqn 1.

$$D_{n,e} = -10.lg\left(\frac{S_{open}}{A_0}\right) \qquad \text{Eqn 1}$$

Where:

S_{open} is the area of the opening, in square metres

A_0 is the reference equivalent sound absorption area, 10 m^2.

Where the value for element-normalised level difference, $D_{n,e}$ is the same in each frequency band (as implied here), the single-figure weighted value, $D_{n,e,w}$ has the same value, and the spectrum adaptation term, C_{tr}, has a value of zero.
Thus $D_{n,e} = D_{n,e,w} = D_{n,e,w} + C_{tr}$.

The proposal in GDC-ADO (10) is to use the "area of the opening" of a partially open window to determine the appropriate sound insulation. However, the "area of the opening" of a partially open window is not well defined.

3.2 Acoustic open area, AcOA

The GDC-ADO proposes that an "acoustic open area" (AcOA) is considered for a partially open window. This is derived by considering a partially open window light as a flat rectangular plane, within a two-dimensional plane façade. This disregards the depth of the window opening light frame and its overlap with the surrounding window frame, and the geometry of the interaction between the opening light and the reveals but represents a simple model.

The AcOA is conceived as the lesser of two potential areas:

- The sum of the rectangular area at the base (of a top-hung window) and the two triangular areas formed on each side of the opening light;
- The width x height (*w* x *h*) of the opening in which the opening light sits.

The potential AcOA is shown in Figure 1, illustrated for a side-hung window. The dimension "*z*" is given by simple geometry as shown in Eqn 2.

$$z = 2 \times w \times sin\left(\frac{\alpha}{2}\right) \qquad \text{Eqn 2}$$

Where:

α is the opening angle.

The area of the top and bottom triangles is given by 0.5 x base x height, which is 0.5 x *w* x *w* x sin(α). Therefore the area of both triangles, top and bottom, reduces to w^2 x sin(α).

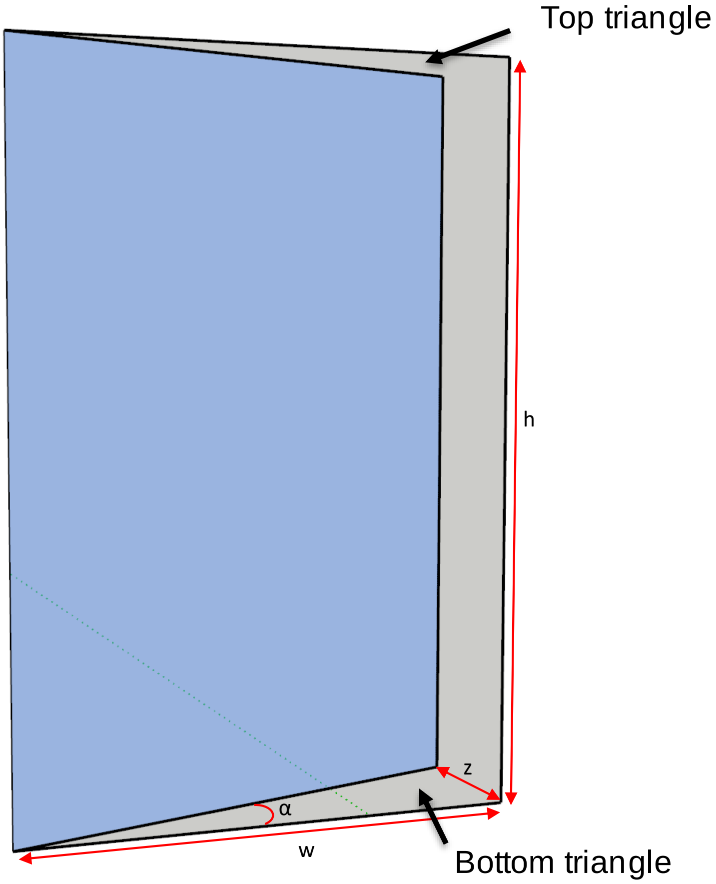

Figure 1: Concept of "acoustic open area"

The total AcOA is given by the lesser of areas from Eqn 3 or Eqn 4:

$$AcOA \leq w^2 \times sin\,(\alpha) + z \times h \qquad \text{Eqn 3}$$

And:

$$AcOA \leq w \times h \qquad \text{Eqn 4}$$

For a given room volume, the partial internal level due to a partially open window can be calculated using Eqn 1, using the methods described by Harvie-Clark (11), as described below.

4.0 Laboratory measurements of open windows

4.1 Proprietary window laboratory tests

Acoustic laboratory tests to ISO 10140-2 (12) are the industry standard method for qualifying the sound insulation of a test element. The test is from a carefully constructed diffuse sound field to a diffuse sound field – i.e. the sound impacts the test specimen from all angles of incidence equally, in theory. The tests (13) present a window with an opening light 1.1 x 0.3 m (*w* x *h*) open to different dimensions. The simple assumptions of the AcOA model are used to determine the AcOA and calculated element-normalised level difference. Comparison with the reported values is shown in Figure 2. This shows very good agreement between measurements and calculated values – to the limit of precision of the reported $D_{n,e,w}$ + C_{tr} values (integer values).

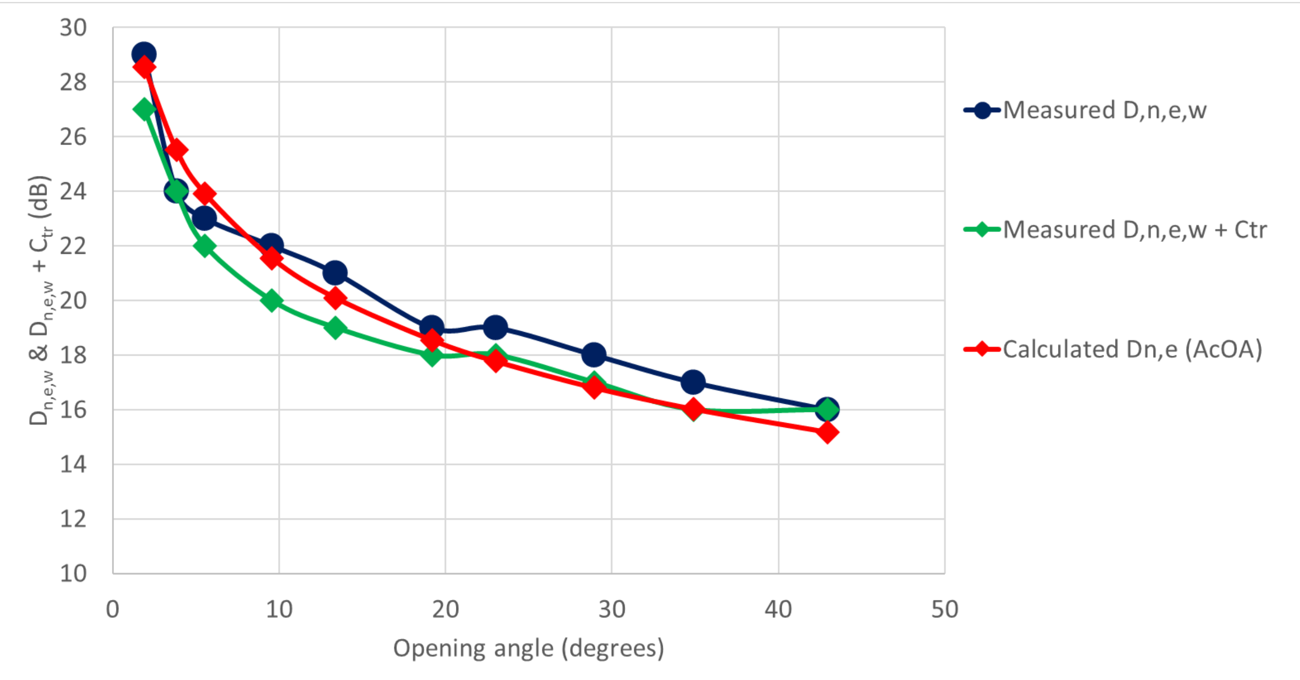

Figure 2: Open window measured laboratory level differences as stated in the Velfac report (13) and the calculated Acoustic Open Area of these openings for comparison

4.2 NANR 116 laboratory tests

The largest laboratory study of partially open windows is reported in NANR116 (14), in which the measurements were not made according to ISO 10140-2, but rather from an anechoic chamber with a discrete sound source (loudspeaker), into a reverberant room. The values reported for the level difference or normalised element level difference, $D_{n,e}$ would be different compared with values measured according to BS EN ISO 10140, but may be more realistic of field conditions.

NANR116 deviates from standard ISO 10140-2 test methods to provide data that is intended to be more representative of field conditions. The report summarises that opening sizes can be broadly represented by the sound insulation levels shown in Table 1.

The corresponding insulation values calculated using the AcOA approach would be 23, 20, 17 dB for 0.05, 0.1, 0.2 m^2 respectively. At larger open areas, the discrepancy between calculated and inferred values is reduced.

Opening size / m^2	$D_{n,e,w} + C_{tr}$
0.05	18
0.1	17
0.2	15

Table 1: Summary of open window sound insulation vs. opening size from report NANR116 (14)

The calculated AcOA and measured level differences are reviewed for the representative range of window types, as shown in Figure 3. The measured values for 0.1 m^2 AcOA (solid blue bars) may be compared with 20 dB (dashed blue line), and the values for 0.2 m^2 AcOA (solid green bars) may be compared with the value of 17 dB (dashed green line). Also included, shown hatched, are the values calculated on the EA for each window arrangement.

The results illustrate a variable difference of no more than 2 dB between measured and calculated values.

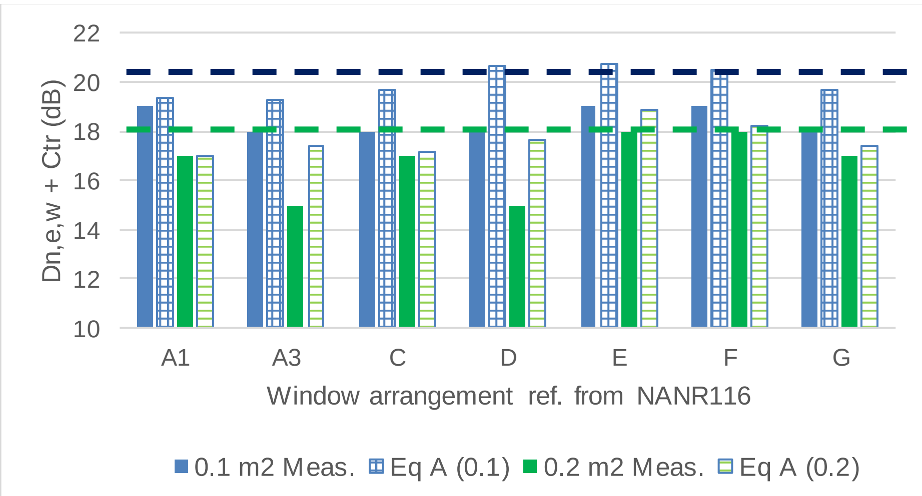

Figure 3: NANR116 (14) measured and calculated level differences. Solid bars are measured values (NB not to ISO 10140). Hatched bars are calculated based on EA. Dashed lines represent the AcOA calculated performance for 0.2 m^2 (blue) and 0.1 m^2 (green) ventilation areas

4.3 Field measurements of opening windows with a loudspeaker

Although the field loud-speaker test method is well established, recent findings question its accuracy when compared with long term the reliability of the model for the global façade sound insulation from the performance of elements, ISO 12354-3, and comparison with measurements according to ISO 16283-3 (15). Scrosati *et al*

(16) concluded that the correlation between the noise level descriptor, L_{den} (outdoor and indoor, measured over 25 days) and façade sound insulation descriptor, $D_{2m,nT}$, measured with a loudspeaker according to ISO 16283-3, is not reliable. They found that the single number quantity including the low frequency adaptation term for road traffic noise, $D_{2m,nT,50}$ measured directly differs by 8 or 9 dB from the value calculated using the correlation, and measured values of L_{den} indoors and outdoors. The loudspeaker measurements in this case had been made in a round robin test, and are therefore the benchmark of representative loudspeaker façade tests.

Nunes *et al* (17) investigated the acoustic performance of open windows, comparing the free field and diffuse field sound reduction for the same proprietary window that was tested in a laboratory as above, but with sound from a loud speaker under controlled test conditions. The proprietary window presented different results between freefield and diffuse field conditions, with a higher performance in freefield conditions. The authors suggested that openable windows should not be tested in diffuse (standard laboratory) conditions. Nunes suggests that laboratory measurements tend to underestimate the sound insulation compared to field measurements of partially open windows. Field measurements showed consistently higher insulation ratings across octave bands. In addition, theoretical calculations based just on open area (i.e. 10 x Log(S), where S is the “open area”) overpredict the reduction in insulation with increasing open area. Sound insulation is shown to improve with increasing angle away from normal incidence, both horizontally and vertically.

Søndergaard *et al* (18) investigated the range of permissible loudspeaker positions relative to the window opening according to ISO 16283-3. This demonstrated a range of 8 – 10 dB for the $R'_w + C_{tr}$ for the different loudspeaker positions, and a value of 6 dB when using road traffic as the sound source.

4.4 Field measurements of opening windows with environmental sound sources

There are a range of studies of the in-situ performance of opening windows, notably Locher *et al* (19) which includes a review of previous significant studies. Locher takes account of windows being closed, open in the tilted position, or open in the turned position – the area of opening is not explicitly identified.

Søndergaard’s study illustrates a discreet difference between loudspeaker tests and tests using road traffic as the sound source.

Ryan *et al* (20) present window open areas and room volumes, along with external and internal level differences and standardized level differences. Ryan reports that the external measurements were made in front of the façade at ground level, and a 3 dB correction was applied to account for this. The method used is the same as the AcOA method (following EN 12354-3: 2000), to a different reference reverberation time than is typically used in the UK (0.35s, c.f. 0.5s). These calculated results are not presented by Ryan *et al*, although based on the data presented it can be calculated as shown in Figure 4, with a reference reverberation time of 0.5 s; this figure also includes the Australian method in AS 3671 (1989). Figure 4 indicates that the AcOA method generally over-predicts the insulation achieved, whereas in the commentary, Ryan indicates that “*in general the calculated level internally was above the levels that the field measurement achieved*”. If this were so, the AcOA calculation method would be prudent, although other evidence presented here suggests the opposite.

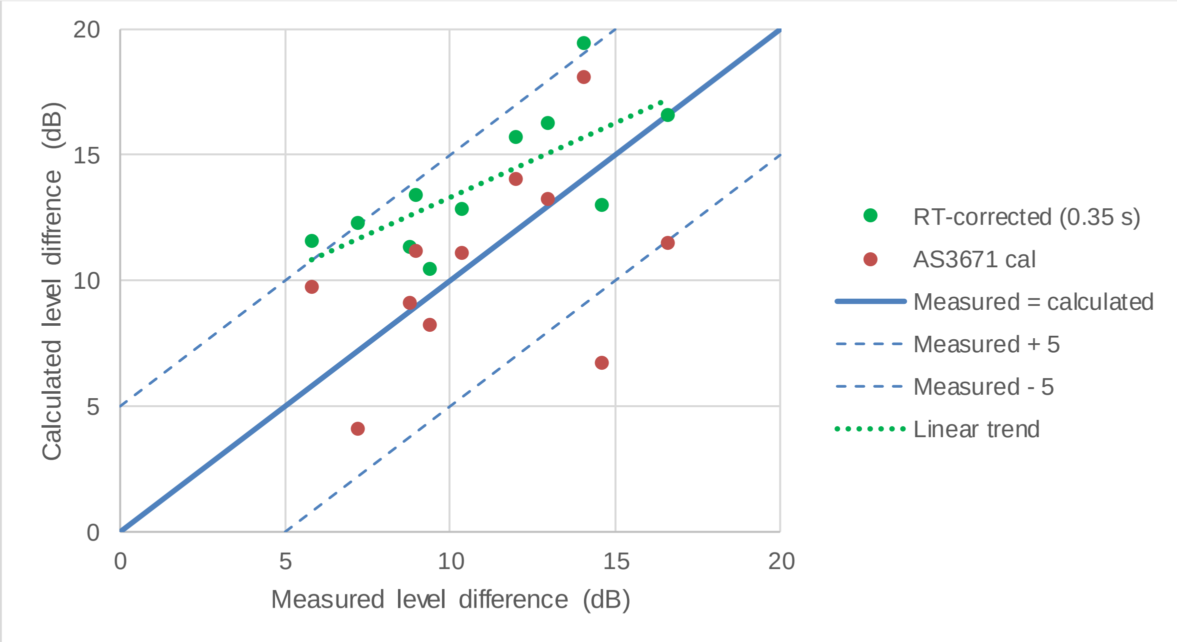

Figure 4: Measurements by Ryan *et al* (20) with the AcOA insulation calculated

5.0 Field Measurements

5.1 Methodology

A range of sites were selected that were exposed to steady continuous road traffic noise, such that the requirements of ISO 16283-3 could be conveniently satisfied. A count was made of fifty vehicles passing the site, to determine the minimum time period for measurements. This varied between 30 seconds and a few minutes for the different sites. Sound measurements were made simultaneously outside, between 1 and 2 m from the façade with a fixed microphone, and inside, using a manual swept microphone technique. Measurements were made in frequency bands (mostly 1/3 octaves, one site in 1/1 octaves) over the relevant frequency range to determine the façade level difference, $D_{nT,2m,w} + C_{tr}$ for each window position. Reverberation time measurements were made with the window closed in accordance with BS EN ISO 3382-2. The key parameters of each site are shown in Table 2, and features illustrated in Table 3.

The window opening extent was measured with a tape measure as illustrated in Figure 5. The measured dimension illustrates the distance between the opening light closed position and its open position. This measurement is considered to be consistent with the simple concept of a partially open window as a flat rectangular plane hinged in a flat plane opening, as described in the Equivalent Area calculator (6). This concept disregards the thickness of the opening light and window frame, and any effect of the reveal. These features may affect both the airflow and sound insulation performance in different ways. The window was opened in 50 mm increments, up to around 400 mm if possible; this leads to a variety of window opening angles and open areas between sites. Measurements were also made of the room volume.

Figure 5: Measurement of window position, illustrating 100 mm stroke length

5.2 Calculations

The internal sound level measurements were standardised to a reference reverberation time of 0.5 seconds. From Practical Acoustic Design – The Apex Method (11), the equation for the standardised internal level due to a single element of performance $D_{n,e}$ can be derived as shown in Equation 5. As the external noise ingress through the partially open window dominates the external noise ingress (ie other noise ingress paths are of no significance), this equation can be used directly to evaluate the performance of the partially open window, $D_{n,e}$.

$$L_{eq,2,nT} = L_{1,2m} - D_{n,e} - 10 \times \log(V) + 15 \qquad \textbf{Eqn 5}$$

Where:

$L_{eq2,nT}$ is the standardised, spatially-averaged internal sound level
$L_{1,2m}$ is the level between 1 and 2 m in front of a plane façade
$D_{n,e}$ is the element normalised level difference
V is the room volume

The calculations are carried out in frequency bands. The single figure quantity, $D_{n,e,w} + C_{tr}$ is calculated according to BS EN ISO 717-1.

Site reference	Room volume (m^3)	Openable pane H x W (mm)	Hanging	Dist. To nearest lane edge (m)
1	29.5	1,355 x 555	Top hung	6.25
2	53.8	730 x 780	Top hung	9.05
3	16.6	1,140 x 780	Side hung	5.50
4	12.1	345 x 770	Top hung	3.30
5	26.5	1,020 x 795	Top hung	13.00
6	26.9	780 x 1,150	Top hung	5.90

Table 2: Summary of Room Parameters (all windows open outwards)

<table>
<tr><th>Site</th><th>Window</th><th>Room, internal</th><th>Window, external</th></tr>
<tr><td>1</td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td></tr>
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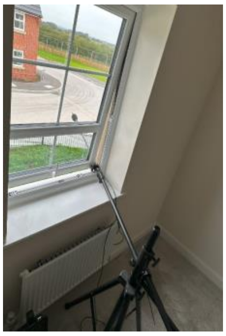
Site	Window	Room, internal	Window, external
4			
5			
6			

Table 3: Window, internal room and external room images of each site

5.3 Results & Discussion

The calculated level difference based on AcOA is according to Eqns 3 & 4; when based on EA, the EA is calculated according to (6). Thus there are three values of level difference determined for each window open position:

- Measured
- Calculated based on the AcOA
- Calculated based on the EA

The window opening position can be given in terms of stroke length as measured (mm), or in terms of opening angle as below, calculated from the simplified model of an opening light as a flat rectangular plane. The results are shown in Table 4 and Figure 6.

Site ref	Opening angle (α)	Acoustic Open Area, AcOA (m^2)	Equivalent Area, A_{eq} (m^2)	$D_{n,e,w} + C_{tr}$ (dB)		
				Measured	AcOA calculated	EA calculated
1	17	0.75	0.47	11.0	11.2	13.2
	15	0.66	0.44	14.4	11.8	13.6
	13	0.57	0.40	14.8	12.4	14.0
	11	0.48	0.35	15.3	13.2	14.6
	8	0.38	0.30	15.8	14.2	15.3
	6	0.29	0.24	16.7	15.4	16.3
	4	0.19	0.17	17.3	17.2	17.8
	2	0.09	0.09	18.9	20.2	20.6
2	32	0.57	0.37	11.7	12.4	14.3
	28	0.52	0.35	12.7	12.8	14.6
	24	0.45	0.32	12.7	13.5	15.0
	20	0.37	0.28	13.4	14.3	15.5
	16	0.30	0.24	13.4	15.2	16.2
	12	0.23	0.19	14.7	16.5	17.1
	8	0.15	0.14	15.9	18.2	18.6
	4	0.07	0.07	18.0	21.2	21.3
3	30	0.76	0.56	14.5	11.2	12.5
	26	0.67	0.52	14.0	11.8	12.8
	22	0.57	0.47	15.2	12.4	13.2
	18	0.48	0.42	15.5	13.2	13.8
	15	0.38	0.36	16.3	14.2	14.4
	11	0.29	0.29	17.8	15.4	15.4
	7	0.19	0.21	16.8	17.2	16.9
	4	0.10	0.11	18.9	20.2	19.6
4	52	0.27	0.20	17.3	15.8	17.0
	42	0.27	0.19	18.0	15.8	17.3
	34	0.22	0.17	17.8	16.6	17.7
	25	0.17	0.14	18.6	17.8	18.4
	17	0.11	0.11	19.5	19.5	19.6
	8	0.06	0.06	20.3	22.5	22.0
5	23	0.72	0.51	13.5	11.4	12.9
	20	0.63	0.47	14.0	12.0	13.3
	17	0.54	0.43	14.2	12.7	13.7
	14	0.45	0.38	14.8	13.5	14.2
	11	0.36	0.32	14.7	14.4	14.9
	8	0.27	0.26	16.2	15.7	15.9
6	20	0.76	0.53	10.3	11.2	12.8
	18	0.67	0.48	10.4	11.7	13.1
	15	0.58	0.44	10.8	12.4	13.6
	12	0.48	0.38	11.6	13.2	14.2
	10	0.39	0.32	11.6	14.1	14.9

Site ref	Opening angle (α)	Acoustic Open Area, AcOA (m^2)	Equivalent Area, A_{eq} (m^2)	$D_{n,e,w} + C_{tr}$ (dB)		
				Measured	AcOA calculated	EA calculated
	7	0.29	0.26	12.9	15.4	15.9
	5	0.19	0.18	13.5	17.1	17.4
	2	0.10	0.10	15.3	20.2	20.2

Table 4: Summary of all data

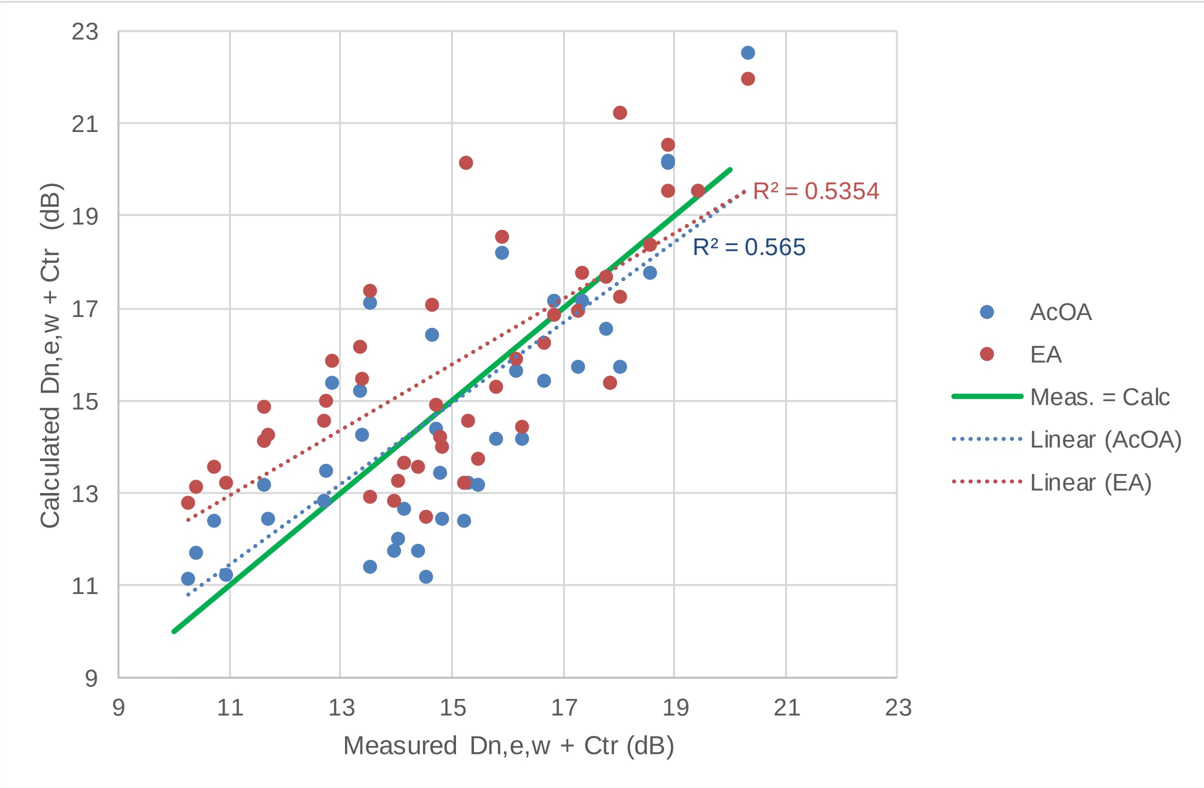


Figure 6: Illustration of all results, calculated by AcOA and EA

Overall, the results show reasonable agreement between the modelled (calculated) values and measured values, on average, although there is quite a large amount of scatter in the data. While the regression line for the values calculated on the AcOA appears to follow the measured values more closely, the uncertainty is not calculated to be reduced by using the AcOA rather than the EA to calculate the performance. It is calculated that 95 % of the calculated values lie within 3.35 dB of the measured values, whether the calculation is based on the AcOA or the EA minus the 95% confidence interval is the same. For higher values of $D_{n,e,w} + C_{tr}$, the EA calculation is more accurate, whereas for lower values the AcOA fits the measured data better.

Note, the performance, whether calculated or measured, varies considerably compared to the rule of thumb '10-15dB'. These performances are for one windowpane.

Where more than one windowpane is assumed to be open in the thermal model, the overall performance from outside to inside is reduced by:

$$10 \times Log(N)$$ **Eqn 6**

Where:

N is represents the number of windowpanes open

With multiple windowpanes modelled fully open at night, this can result in an outside to inside level difference of as little as 5 dB.

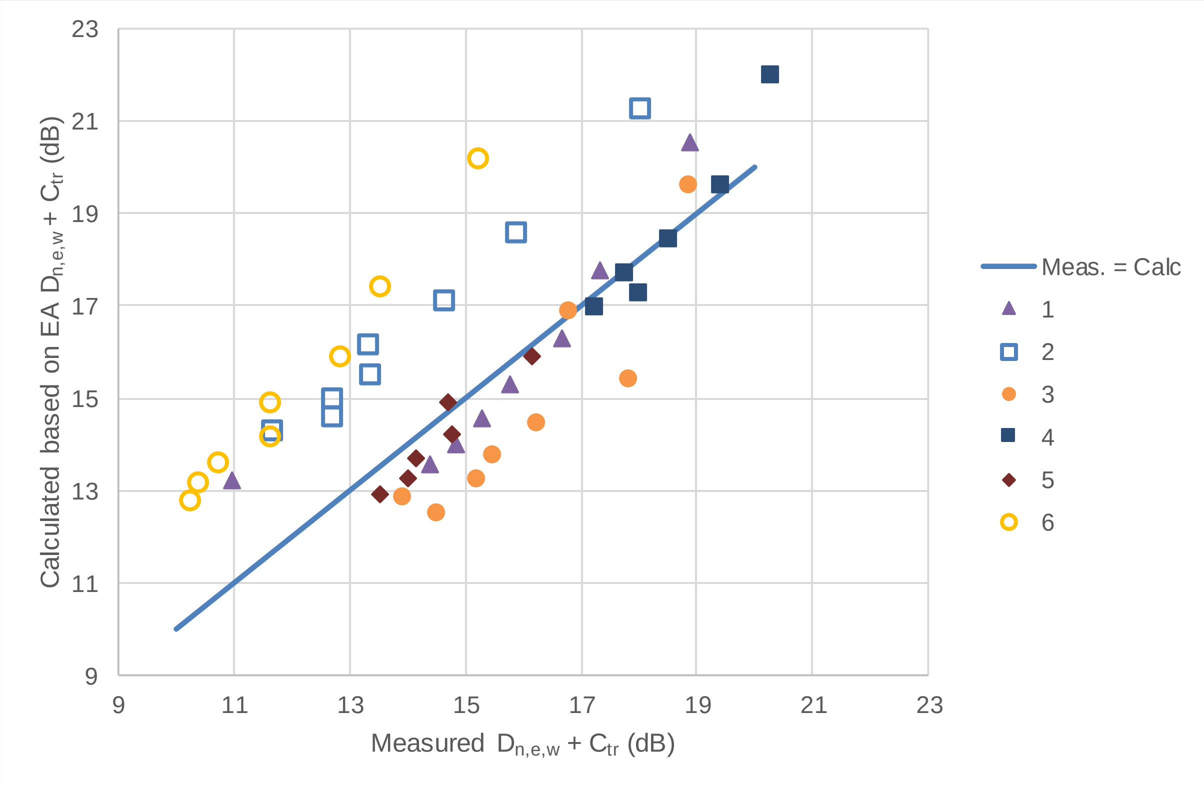


Figure 7: Illustration of all results by site, calculated by EA

If the data is reviewed on a site-by-site basis, as shown in Figure 7, it can be seen that two sites, #2 and #6, exhibit a markedly different pattern from the other sites. Other sites also have outlying points (see especially site #1 lowest value, site #4 highest value). This suggests that it may be possible, with further data, to subdivide the single classification of a “partially open window” to gain a more accurate calculation, if this is considered desirable.

Sites #2 and #6 are both the only fully furnished (occupied) rooms. The amount of sound absorption should not make a difference to the measured façade sound insulation performance. Site #2 is also differs from others in that the opening light does not hinge from the side of the frame, but the hinges allow a certain amount of rotation of the opening light. This means that the simple geometric model of an opening light as a flat plane in a flat plane opening is quite different from the reality; the additional opening around the other edges of the opening light in practice may permit more external noise ingress than other window opening light arrangements.

Site #6 has the external measurements at ground level, with the opening window at first floor level. There is a low wall between the external microphone position and the road, which could lead to lower sound levels at the microphone position than those incident on the façade at first floor level. As the façade is also close to the road, there may be a line of sight from the road directly into the room – it has been demonstrated (17), (18) that the insulation of an open window is sensitive to the angle of incidence of incoming sound.

6.0 Modelling overheating risk

According to Petrou *et al* (21), Tian *et al* (22) explains that building performance simulation uncertainty can be classified into two broad categories: Model Form; and Parameter Uncertainties. Empirical validation work has demonstrated how the combination of both types could lead to significant discrepancies between the model and actual indoor environment, according to Strachan *et al* (23). Petrou *et al* focus on the magnitude of possible parameter uncertainties associated with the modellers' algorithm choice.

In the thermal model, a façade opening permits air exchange between inside and outside. The complexity of this in practice is described by Sharpe *et al* (5), who describe 15–25 % prediction errors of free area models commonly used in practice. The options available to modellers are complex; default practices are adopted that are generally considered to be "good practice" (24).

Petrou *et al* (25) demonstrated that the choice of building simulation tool, with default algorithm options, significantly affected the prediction of overheating risk. Wind-driven ventilation and surface convection algorithms were the main sources of the observed discrepancies. The choice of algorithm within each building simulation tool was investigated by Petrou. The selection of non-default algorithms within each model also had a very significant impact on the results. Roberts *et al* (26) compared predictions and measurements of overheating risk in synthetically occupied test houses. It is understood that TM59 is currently under revision, especially with the updated science around tolerable night time temperatures in bedrooms according to Lomas and Li (27).

7.0 Practical façade assessment for sound insulation and thermal comfort

The façade sound insulation performance that may be achieved depends on the type of incoming sound field (degree of diffusivity), angle of incident sound, arrangement of opening light, reveal depth, opening type, and internal room conditions. Most of these factors are not known or even knowable with current technology. Ryan *et al* indicate that there are additional unknowns when considering L_{max} sounds. Based on wide experimental data by Scrosati *et al*, façade sound insulation is not recommended to correlate external and internal sound level descriptors, when using loud speaker tests to characterise the façade performance.

7.1 AcOA equated with EA

The use of the AcOA is based on an engineering concept of the façade opening and ISO 12354-3. “All models are wrong - some are useful”, according to George Box (28). While there is a theoretical justification for using AcOA, there is no physical basis for using EA. However, the measurements presented here demonstrate that there is no additional uncertainty introduced by the use of EA as opposed to AcOA.

The proprietary window laboratory tests have a calculated EA that matches almost exactly the AcOA, therefore there is no loss of accuracy. The NANR116 data indicates that using EA in this way makes a variable small difference to the predictions – sometimes they are more accurate, sometimes less.

There is a very significant practical advantage in calculating façade sound insulation based on EA, as this aligns with the performance parameter in the thermal (aerodynamic) model. It greatly facilitates the exchange of model attributes with the overheating modeler. The most significant advantage is that in the design process to assess thermal and acoustic compliance with guidelines, both disciplines use the same values to assess the performance of a partially open window. This also overcomes any need to know the window dimensions and angle of opening – all the details of the façade are bypassed in the models. Many modelers and other practitioners find the description of AcOA difficult, and especially so to translate into the intended EA. The combined assessment of thermal and acoustic compliance is complicated – basing the sound insulation on the EA simplifies the process, and reduces the risk of greater discrepancies between acoustic modelling assumptions and thermal modelling assumptions.

8.0 Conclusion and further work

It is suggested that the sound insulation of façade openings may be based on either Acoustic Open Area, AcOA or Equivalent Area, EA with equal uncertainty based on the preliminary measurements presented. There are significant practical advantages to the use of EA over AcOA in the modelling for new buildings. Further work is required to expand the data set to a representative sample for the range of different conditions encountered in practice. The performance may also vary with aircraft sound which impacts a partially open window from a different angle.

There is uncertainty in the prediction of the façade sound insulation of a partially open window. Many advances in acoustic measurements, modelling, laboratory tests, and standardization of these new methods would be required to significantly reduce this uncertainty. The acoustic industry will need to judge if this is a priority, or if simple methods are considered sufficiently accurate. A risk of this approach is that practical details that could improve the sound insulation – for example, a side hung window opening away from the main noise source, rather than towards it – is not accounted for, and hence has no value in the design, whereas it could make a noticeable difference in practice.

Acronyms

AcOA	Acoustic Open Area
ADO	Approved Document O (2)
ADO-FAQ	ADO Frequently-asked-questions (3)
CIBSE TM59	Design methodology for the assessment of overheating risk
EA	Equivalent Area
GDC-ADO	Draft Guide to Demonstrating Compliance with noise requirements of ADO (10)
IOA	Institute of Acoustics
WHO GCN	World Health Organisation Guidelines for Community Noise (8)

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