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Natural Ventilation News

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THE NEWSLETTER
OF THE
CIBSE NATURAL
VENTILATION GROUP

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From the Chair

Welcome to our latest newsletter from the Natural Ventilation Special Interest Group. I write this introduction amidst strange times, who could have foreseen a few months ago that great swathes of the global population would be undergoing various social distancing regimes, with many people under lockdown. Although the risks of a worldwide respiratory pandemic have been highlighted over recent decades, the true impact of such a devastating global pandemic could never have been anticipated. Our thoughts and sympathies of course are given to those who have lost friends and family prematurely to this new disease and we look for a hopeful future where we work globally to find solutions to find solutions to the Covid-19 pandemic.

We will all be facing a new normal in the coming years, as the last few weeks have seen dramatic changes in the way that we work, socialise and connect. Great leaps have been made, that ordinarily may have taken years to implement: Parliament debating remotely, home working and meetings surely challenges the need to commute daily, GPs able to provide telephone and video consultations. Perhaps we are witnessing the implementation of new ways of doing things at a rate of change the likes of which we haven't seen since the industrial revolution. As building service engineers with an interest in indoor air quality, we have an extremely important role, for a long time ventilation and air quality has been the poor relative of energy efficiency in the battle for climate change. Too often we see buildings celebrated for their energy efficiency only to discover that the ventilation rates are inadequate or not properly controlled. Perhaps now is the time to reinforce our desire to see holistic solutions to building design, solutions that see an energy reduction in use rather than just in computer models, solutions that see not only energy efficiency, but ones that create an indoor environment to improve the wellbeing of the occupants. It is timely that CIBSE have just published TM40 – Health and Wellbeing in Building Services http://tiny.cc/jdsdnz, which is an attempt to create such an holistic approach.

In this edition of the newsletter Dzhordzhio Naldzhiev introduces some of the work he has been undertaking to explore measures of air quality in domestic buildings – with particular interest in the impact of off-gassing from some of the materials that are being used to insulate homes. Again, a challenge for us to consider the impact of material choice beyond meeting a required U-Value. Likewise, with respect to the design of openings in buildings for natural ventilation Patrick Sharpe has been investigating our knowledge of airflow through windows. This work raises some important issues with respect to the predicted airflow through an open window dependent upon the way we might measure the window opening area – with some methods predicting 40% more airflow through the window then can actually be achieved!

In May 2020 we also celebrate the 200th Anniversary of the birth of Florence Nightingale, who not only was pivotal in the creation of modern nursing, but also a big promoter of adequate ventilation – especially within the health setting. Today we need to take up her mantle and promote good ventilation. Evidence is mounting that SARS-CoV2 can transmit via aerosols, and poorly ventilated spaces will therefore increase the length of exposure and risk of transmission. CIBSE, REHVA and ASHRAE have made recent statements that acknowledge the need for good ventilation to reduce risk of transmission (REF1). There is a substantial body of evidence of inadequate ventilation in a lot of our buildings – quite often through poor understanding of the ventilation design by occupants and poor control. We need to promote a better understanding amongst building users so that they can appreciate how the ventilation design works and operates. Furthermore, as we approach the summer we should also be promoting ways of mitigating overheating in domestic buildings. With many vulnerable people requested to self-isolate indoors, and more people working from home, we should be helping to ensure occupants can use passive measures to improve their internal environment and thermal comfort. Now, more than ever before, it is prudent on building service engineers to take the lead and work towards a future of improved indoor environments.

Dr Chris Iddon – chair of the CIBSE Natural Ventilation Group.

REF1
https://www.ashrae.org/technical-resources/resources

https://www.rehva.eu/activities/covid-19-guidance

http://www.cibse.org/coronavirus-covid-19/coronavirus-covid-19-and-hvac-systems

My Chemical Romance– Our Relationship with Chemicals from Building Products

Dzhordzhio Naldzhiev, UCL

Everything is made up of chemicals. Some are good for people, some are not. Some are good for the environment, some are not. Chemicals that are good for the environment may not be necessarily good for you, and vice versa (1). For indoor air quality purposes, we split those chemicals depending on the temperature at which they turn from liquid to gas: VVOCs (very volatile organic compounds), VOCs (volatile organic compounds) and SVOCs (semi-volatile organic compounds). The VOC terminology is not related in any way to the impact on human health. The ability of organic chemicals to cause health effects varies greatly from those that are highly toxic, to those with no known health effect. As with other pollutants, the extent and nature of the health effect will depend on many factors including level of exposure and length of time exposed.

Many VOCs used widely in construction products, appliances, furniture, toys, cleaning products and personal cosmetics have limited health-related data to determine their impact on our bodies and what concentration constitutes "safe". We spend > 60 years of our lives indoors and breathe > 11,000 litres of air every day, so the hundreds of different VOCs entering our system could impact our bodies in many harmful ways depending on the concentration and exposure period (2). We found out back in the 80s that personal exposure to VOCs is higher than indoor VOC levels, which is in turn higher than outdoor VOC levels (3) as shown in Figure 1.

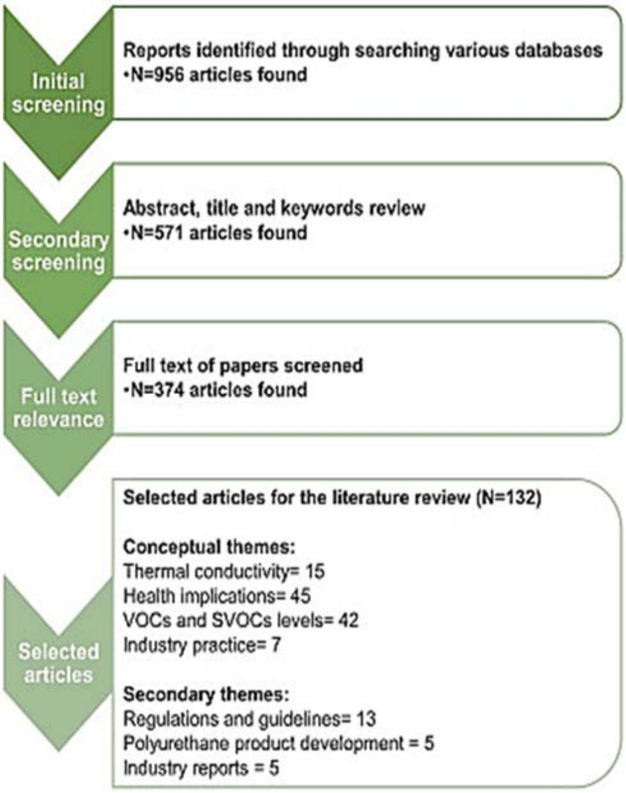
In the last decade, we found out that although products, such as floorboards, have been improved to emit less formaldehyde (4), median concentrations in modern homes remain similar to homes built in the 90's due to better airtightness in energy efficient modern designs (5).

Our research aims to address some of the indoor air quality unknowns and challenges within the context of retrofitted buildings. The focus of my work is the relationship between VOC emissions from insulation materials and ventilation strategies required to provide good indoor air quality.

Figure 1. Relative VOC concentrations (human exposure- highest, indoor air concentration- medium, outdoor air concentration- lowest)

Our latest research paper explores the emissions from polyurethane (PU) products and how they impact indoor environmental quality. We systematically reviewed 132 publications covering VOCs, SVOCs and their implications on human health from products such as insulation materials, mattresses, pillows, car seats and other PU products (6).

We examined all chemical emissions from PU products and concentrations found in real environments throughout the



Reports identified through searching various databases
•N=956 articles found

Abstract, title and keywords review
•N=571 articles found

Full text of papers screened
•N=374 articles found

Selected articles for the literature review (N=132)

Conceptual themes:
Thermal conductivity= 15
Health implications= 45
VOCs and SVOCs levels= 42
Industry practice= 7

Secondary themes:
Regulations and guidelines= 13
Polyurethane product development = 5
Industry reports = 5

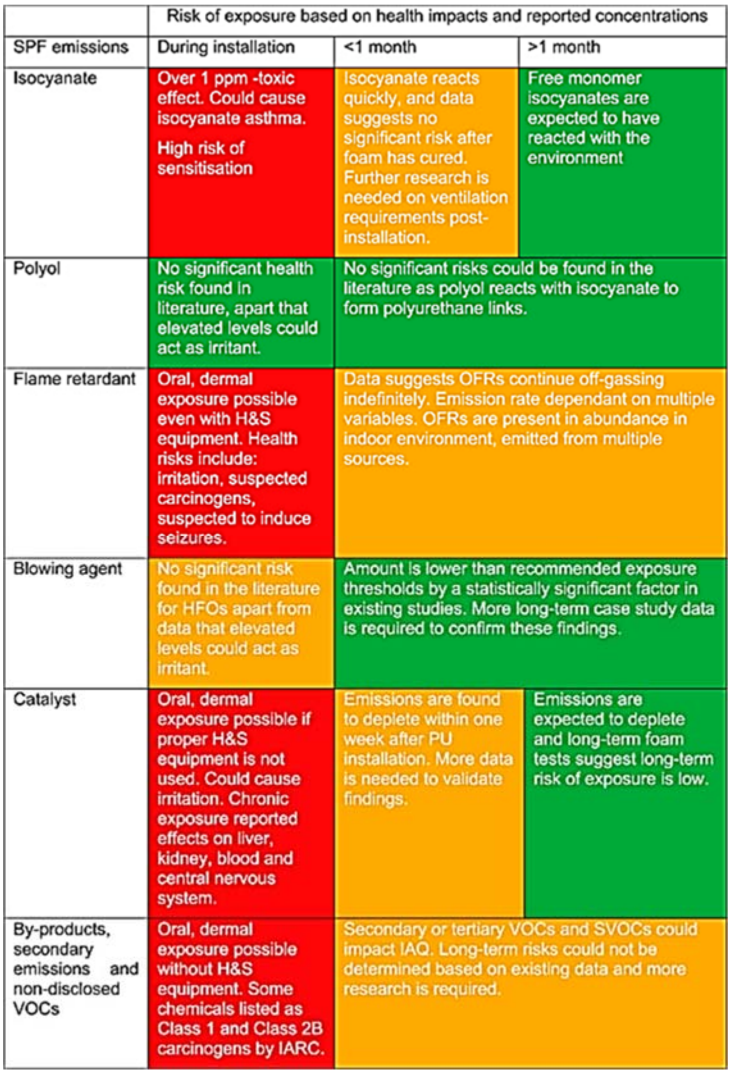
Figure 2. Flow diagram of screening process and paper selection. (6)

entire product lifecycle - raw materials, emissions during production, application and use and even extreme scenarios such as emissions during fires.

Our study (Figure 2):

- Quantifies the energy efficiency and thermal comfort benefits of polyurethane products compared to conventional insulation materials.
- Reviews the impact of emissions from isocyanate-based products, present in indoor environments, on health.
- Reviews the measured VOCs and SVOCs during a product's lifecycle, with a focus on insulation materials.
- Reviews current SPF application practices in the context of worker protection and IAQ.
- Develops a risk matrix for SPF emissions and suggest further areas of research.

Our study demonstrates that flame retardants, which are subject to growing public interest (7,8,9,10), are found in abundance in indoor environments even in buildings without any PU insulation. This publication builds upon our method development work and experimental emissions testing from buildings materials (11, 12, 13). Our combined data demonstrate why it is crucial to record concentrations of all chemicals using precise analytical chemistry tools (thermal desorption-mass chromatography- gas spectrometry or TD-GC-MS). TD-GC-MS allows us to collect VOCs from the air into small tubes, analyse each individual VOC in that sample and quantify its concentration down to 1-5 ppb in some cases. Figure 3 outlines the risks associated with some of the VOCs emitted from PU products throughout their lifecycle based on health risks, measured concentrations and potential exposure (6).



	Risk of exposure based on health impacts and reported concentrations		
SPF emissions	During installation	<1 month	>1 month
Isocyanate	Over 1 ppm -toxic effect. Could cause isocyanate asthma. High risk of sensitisation	Isocyanate reacts quickly, and data suggests no significant risk after foam has cured. Further research is needed on ventilation requirements post-installation.	Free monomer isocyanates are expected to have reacted with the environment
Polyol	No significant health risk found in literature, apart that elevated levels could act as irritant.	No significant risks could be found in the literature as polyol reacts with isocyanate to form polyurethane links.	
Flame retardant	Oral, dermal exposure possible even with H&S equipment. Health risks include: irritation, suspected carcinogens, suspected to induce seizures.	Data suggests OFRs continue off-gassing indefinitely. Emission rate dependant on multiple variables. OFRs are present in abundance in indoor environment, emitted from multiple sources.	
Blowing agent	No significant risk found in the literature for HFOs apart from data that elevated levels could act as irritant.	Amount is lower than recommended exposure thresholds by a statistically significant factor in existing studies. More long-term case study data is required to confirm these findings.	
Catalyst	Oral, dermal exposure possible if proper H&S equipment is not used. Could cause irritation. Chronic exposure reported effects on liver, kidney, blood and central nervous system.	Emissions are found to deplete within one week after PU installation. More data is needed to validate findings.	Emissions are expected to deplete and long-term foam tests suggest long-term risk of exposure is low.
By-products, secondary emissions and non-disclosed VOCs	Oral, dermal exposure possible without H&S equipment. Some chemicals listed as Class 1 and Class 2B carcinogens by IARC.	Secondary or tertiary VOCs and SVOCs could impact IAQ. Long-term risks could not be determined based on existing data and more research is required.	

Figure 3. Summary of exposure of VOCs and SVOCs during SPF installation, during the first month after retrofit and long term (>1 month) at standard operating conditions. (6)

Our research focuses on measured pollutant data, which could be supplemented with perception-based surveys. People are useful reference tools when it comes down to expressing the sensation of feeling "hot" or "cold". However, when it comes to assessing air quality, our perceptions are often unreliable, vary hugely between individuals and are difficult to calibrate (for example people may find 'new car smell' pleasant even though the VOC emissions from cushion foam, fabrics and fittings – and consequently their impact on air quality - are at their highest). It is therefore crucial to understand the limitations of both our equipment and our opinions. And whilst TVOCs sensors and measurements might offer some indication of overall pollutant levels, TVOC is a crude metric that does not provide us with a full picture of the indoor pollutants impacting health. For example, it could miss out a whole range of pollutants hiding in dust. Our paper shows that concentration of flame retardants in dust (ng/g) is up to 300 times higher than concentration in air (ng/m^3) (6).

The next phase of my research plans is to record long-term (6-12 months) emission rates from various PU materials. The results will allow us to understand how VOC emissions vary over time. I plan to supplement laboratory findings with real-life data from field studies in homes.

We believe the data will provide a better understanding of how building furnishings and building materials interact with the indoor environment and how their emissions could be controlled through ventilation strategies. My laboratory and field work data could be used for the development of robust air quality simulation tools and coupling IAQ and energy models.

These tools will allow us to simulate, design, construct and operate low carbon buildings that not only minimise impact on our bodies, but also enhance our quality of life. Buildings that improve our health and productivity and are fit for the 21st century climate crisis.

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What we think we know about windows and why we are wrong

Patrick Sharpe, Nottingham University

Background

Currently, some methods for calculating window effective area can overestimate the amount of airflow by as much as 40%. As a result, in-situ airflow can be considerably less than that which is predicted during the design phase, leading to greater overheating risk. Interaction with sills and reveals caused by the installation of openings in a façade can further restrict flow, and the presence of external wind can reduce ventilation performance substantially. Failing to understand and account for these effects can lead to systematic failure of natural ventilation systems, resulting in uncomfortable, under-ventilated buildings which damage the reputation of natural ventilation as a whole.

Some of these errors are well understood, and techniques have been developed to account for them. Others however, are less well studied, and require more information to properly characterise. In order to start accounting for these effects, it is necessary to examine the sources of these errors and investigate the scope of the problem.

How we design naturally ventilated buildings

When designing a naturally ventilated scheme, it is common to use the simple envelope flow models described by CIBSE Applications Manual 10[1]. The main attraction of these models is their simplicity – often hand calculations are sufficient in the early design stage. These simple models are used as the ventilation engines of many dynamic thermal modelling tools, and form the basis of more complex airflow network models such as CONTAM[2].

During the design process, a set of environmental conditions is specified which exert a known pressure field across the building. The next task is to size and locate the openings. This requires knowledge of the aerodynamic properties of the opening – i.e how much air is admitted at a given pressure difference. Understanding this behaviour is critical to the performance of the building – overestimating airflow rates could lead to under-ventilation or overheating issues, and underestimating airflow rates could lead to increased capital and operational costs. These are key factors that undermine the reputation of naturally ventilated buildings.

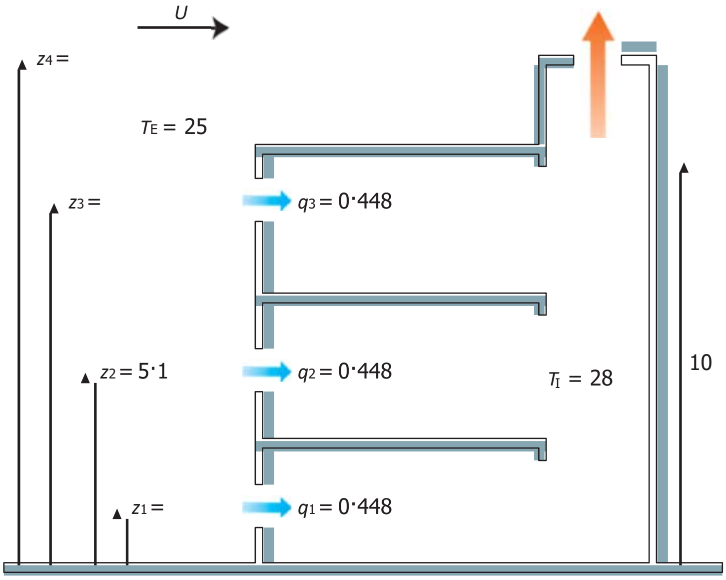
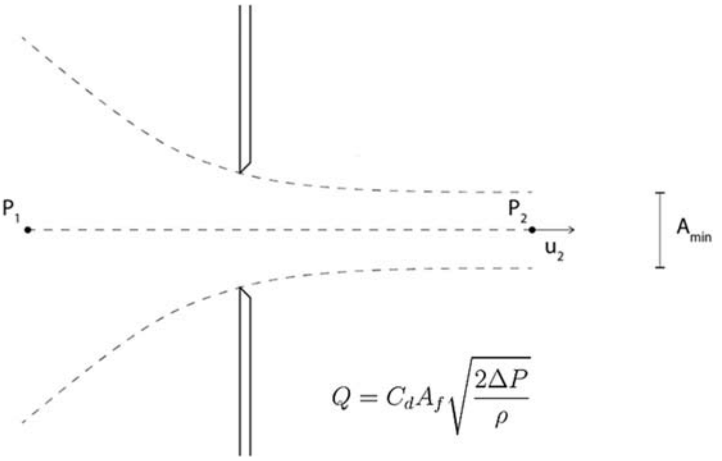


Figure 1. Example of an envelope flow model used in the design of a naturally ventilated building[1].

Modelling flow through openings

In both industry and academia, it is common to model airflow through openings using the orifice flow equation Figure 2). This relates the volume flow rate through an opening to the pressure drop across it, characterised by a constant aerodynamic property specific to that opening known as the effective area. Amongst other things, this equation assumes that the air on either side of the opening is still – something which is evidently not true in the presence of wind.

Even this heavily simplified model is subject to misinterpretation and ambiguity when applied to real windows. The 'free area' is defined as the minimum geometric area of the opening through which the flow passes. This is calculated by inspection of the window geometry to find the total unobstructed area. Even for simple window geometries the process is open to interpretation, and different practitioners approach it differently. Figure 3 illustrates six different methods used in both industry and academia to calculate the free area of the same window type. Each of these techniques would produce different predictions of aerodynamic performance, which could lead to critical errors in performance.



$$Q = C_d A_f \sqrt{\frac{2\Delta P}{\rho}}$$

Figure 2. Orifice flow model of window openings.

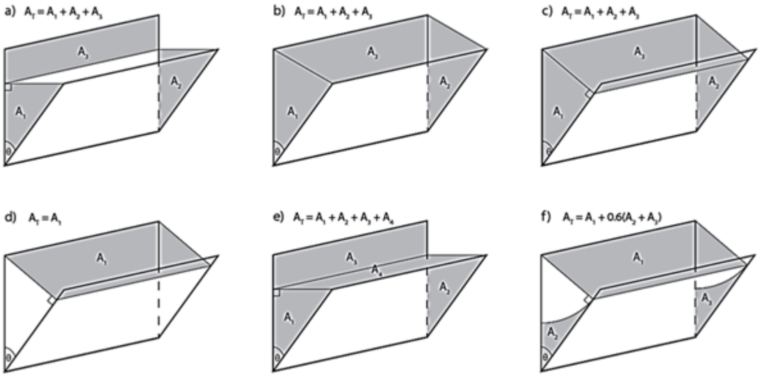


Figure 3. Illustration of the range of approaches to measuring 'free area' applied in industry and academia.

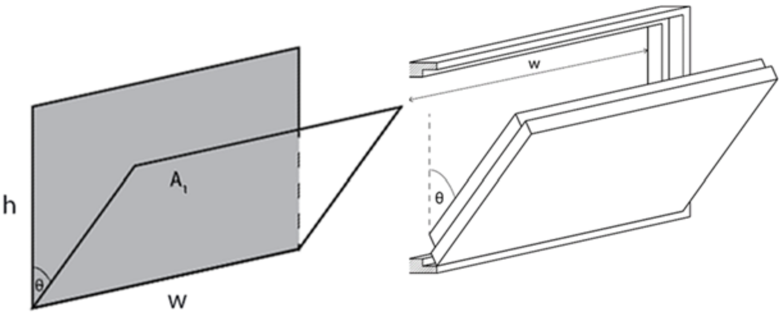


Figure 4. Simplified, unambiguous method of measuring window area proposed in BB101[3].

Existing solutions

Building Bulletin 101[3] presents a method designed to reduce the errors associated with measuring free area. This document suggests defining the area simply as the internal area of the frame (or opening throat) as in figure 4, and defining the discharge coefficient as a function of opening angle and aspect ratio. This property can be determined empirically by experiment, and figure 5 compares the mathematical model presented in BB101[4] with experimental results. This provides a convenient tool to allow designers to make unambiguous predictions of aerodynamic performance of openings, as well as providing a format for window manufacturers to present empirical data. It's worth noting that the performance curves are valid only for geometrically similar windows. Changing the aspect ratio, thickness to height ratios or opening mechanism will alter these performance curves, and data would need to be provided to quantify the effect of this.

This empirical model of opening performance allows the performance of the 'free area' models shown in figure 3 to be evaluated. The graph shown in figure 6 plots the systematic error associated with using one of these 'free area' models for a range of different opening proportions. This suggests the use of free area models commonplace in industry could result in overestimations of air flow rates of up to 40%.

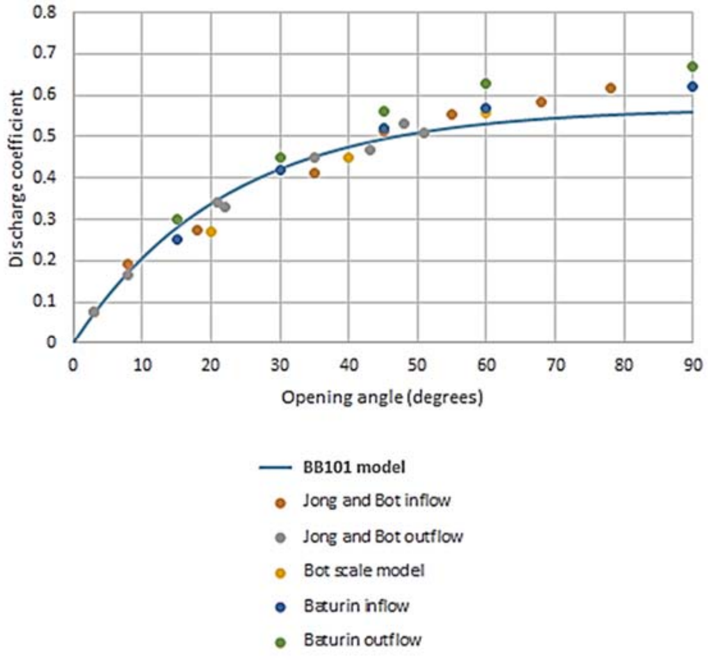


Figure 5 – BB101 model for predicting the discharge coefficient of open windows (presented here for 1:1 aspect ratios)[3,4]

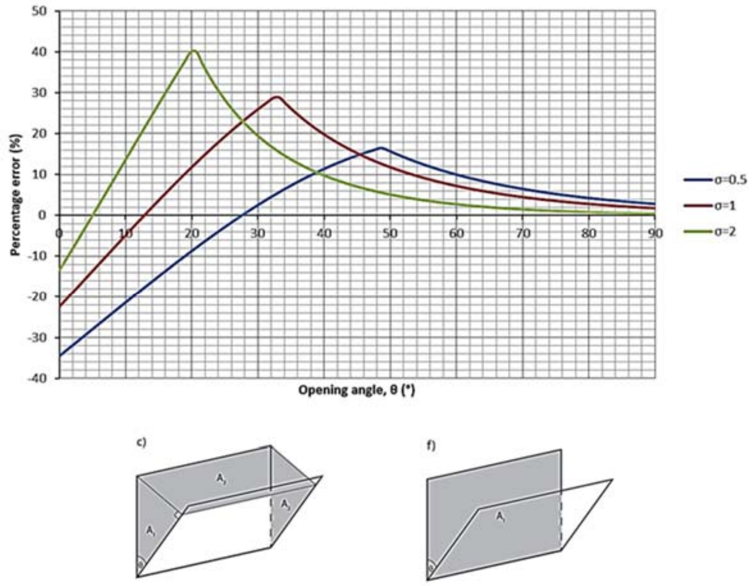


Figure 6. Comparison between free area model (c), where Aeff = 0.61max(h x w ; A1 + A2 + A3), and empirical model (f), where Aeff = Cd(h x w), for a range of different aspect ratios, where σ = height/width.

Influence of external wind

The empirical models described in BB101 rely on data derived from still air tests. These enable the aerodynamic properties of windows to be well characterised in the absence of wind, but do not tell us much about their behaviour in wind driven conditions. The presence of wind can have significant impacts on ventilation performance, but the nature of its effect is poorly understood.

When wind is incident on a building, it tends to generate air motion on the building surface as shown in figure 7. These flows occur parallel to the opening plane and can interact with window geometries in two key ways. Firstly, openings that project into the external flow can act as a wing-wall, creating a build-up or reduction in pressure local to the opening, which can either reinforce or inhibit airflow (see Figure 8). In some cases, this effect can be significant enough to stop or even reverse the airflow through the opening. The second effect is one that has even been observed in simple orifices. As the velocity of the external flow increases, a substantial reduction in the discharge coefficient is measured – reducing to zero at the limit (Figure 9). It is thought that this is caused by a change in the shape of the flow stream due to conserved momentum in the cross flow, and by a loss in total pressure as the flow turns to enter the building. This is another source of error, which is typically unaccounted for in natural ventilation design, and results in the systematic overestimation of airflow rates.

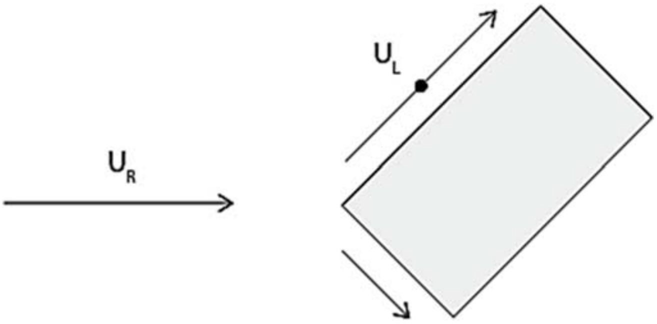


Figure 7. Incident wind generates flows parallel to the building surface.

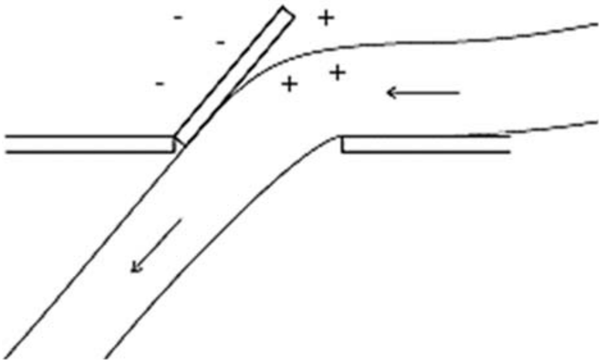


Figure 8. Diagram of how projecting window geometries interact with the surface flow.

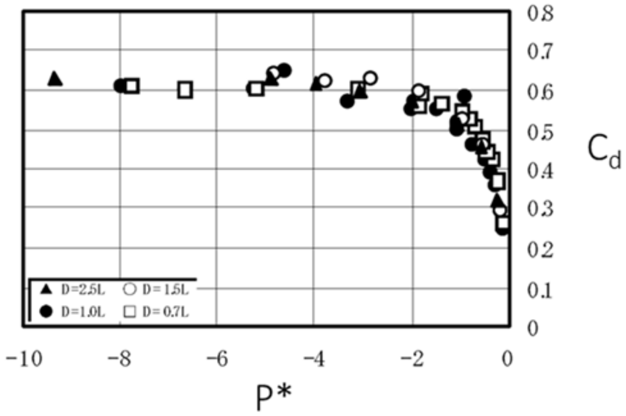


Figure 9 – Graph plotting the reduction in discharge coefficient at low pressure ratios (where P is the ratio between the pressure difference across the opening to the dynamic pressure in the crossflow)*[5].

Influence of wall build up

In addition to the effects of window geometry, the integration of the window into the wall can make a big difference to performance. Firstly, recessing window openings into the wall can help to shield them from the influence of external wind (see Figure 10). It's possible this may make predictions of building performance from still air data more reliable, but it should be stressed that there is not yet any empirical evidence to support this claim.

Secondly, sills and reveals can interact with the window geometry to reduce the available area through which air can pass (Figure 11). This would reduce the performance of the opening when it is installed. The range of parameters that could affect this is large, so the creation of generic data to describe this behaviour would be difficult. Commonly, 'free area' models are used to describe this reduction in performance, but these would be subject to the same sources of error described earlier.

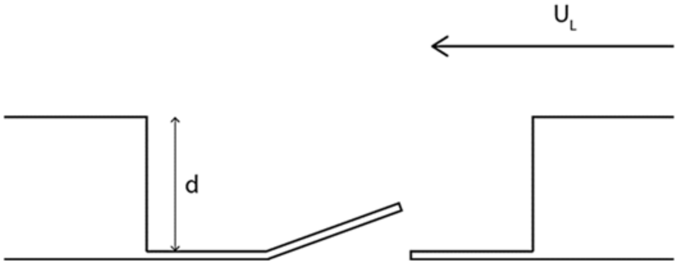


Figure 10. Diagram of opening recessed within a wall build up.

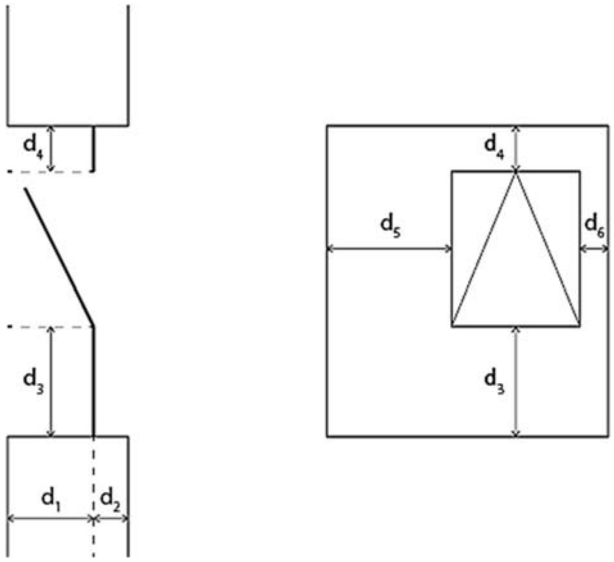


Figure 11. Diagram showing location of an opening in a wall build up which could restrict flow.

Conclusions and guidance for practitioners

The methods commonly used to size and predict airflow through windows do not currently account for the effects of either wind or opening geometry appropriately. Neglecting the influence of these parameters leads to systematic, substantial overestimations of airflow rates, which could lead to under-ventilated, overheating buildings. These errors damage trust in naturally ventilated buildings, and perpetuate the idea that natural ventilation is risky and unreliable.

Accounting for these errors, however, is not easy. Errors in accounting for window geometry for simple openings can be resolved using the method prescribed in BB101, but this doesn't apply when the wall build-up interferes with opening performance. Quick evaluations using 'free area' models could be used, but it must be accepted that these introduce significant errors that need to be designed for. Alternatively, still air tests using scale models can be used where more reliable performance data is required.

The impact of wind is also difficult to account for. In the absence of empirical data, it might be expected that inward opening windows would interact less with the external flow, and thus provide more reliable performance. However, a reduction in performance at high wind speeds is unavoidable.

Experimental work is currently under way at the University of Nottingham to characterise these behaviours for generic window types, as well as developing a standard test methodology that manufacturers and designers can use to test their window and façade designs.

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Future Events and Notices

CIBSE LIVE BUILD2 PERFORM
24-25 November 2020
Olympia London

CIBSE Build2Perform Live 2020 is a free to attend two-day event that brings together over 2,000 built environment professionals; representing all sectors of the building services sector. Returning to Olympia, London, on the 24-25 November 2020, it will connect with over 70+ suppliers, manufacturers, consultants, and advisers who will be ready to answer your questions, discuss solutions and help maximise your time at the event. There will also be parallel seminar sessions. The NVG has regularly taken part in this event and will again be contributing to Build2Perform at Olympia in London this year. A programme of events will be published shortly.

Details:

CIBSE Build2Perform Live is the UK's premier event for built environment solutions.
Free to attend at London Olympia, 24 & 25 November 2020.

Web: www.build2perform.co.uk/

Register for a Free Ticket

Seminar Programme

Publication: Acoustics, Ventilation and Overheating Residential Design Guide

The Association of Noise Consultants has recently published an Acoustics, Ventilation and Overheating Residential Design Guide. This contains much useful information pertaining to delivering a holistic design to ensure both adequate indoor air quality and minimising noise.

This publication can be downloaded from: https://www.association-of-noise-consultants.co.uk/avo-guide/

About the CIBSE Natural Ventilation Group

The CIBSE Natural Ventilation Group was founded in 1994. The committee comprise some 55 members serving a wider membership of over 10,000. The aims of the group are:

- To ensure natural ventilation is properly considered at the design stage equally with mechanical ventilation or air conditioning;
- To disseminate knowledge via seminars and publications; To recommend research projects;
- To be at the forefront of knowledge about the low energy, environmental and economic performance of natural ventilation;
- To work with consultants, contractors, manufacturers and researchers in pursuing these aims.

Disclaimer

The views and opinions in this journal are those of the authors and do not necessarily reflect those of their employers or the CIBSE Natural Ventilation Group.

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