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Natural Ventilation News

THE NEWSLETTER OF THE CIBSE NATURAL VENTILATION GROUP

this issue

Build2Perform Special Edition

www.cibse.org/nvg

About Natural Ventilation News

This Newsletter is produced by the CIBSE Natural Ventilation Group Management Committee to inform members and potential members of the work being undertaken by the Group to benefit the discipline of natural ventilation within CIBSE. The management committee wish to encourage contact with all interested partners. Communication can be directed to the Group at the CIBSE Offices or to individual Management Committee members.

Editor

This edition has been compiled by Dr. Martin Liddament.
NVG Chairman

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CIBSE LIVE BUILD2 PERFORM
21-22 November 2017
Olympia, London

Special Edition - Build2Perform Live Natural Ventilation Group Seminar Report

CIBSE's flagship technical event Build2Perform Live was held at Olympia in London on 21-22 November 2017. Its purpose was to combine two days of interactive technical seminar streams with an industrial exhibition bringing built environment professionals and the wider supply chain together. Over 175 presenters contributed to 80 technical sessions. Almost 2000 people (excluding speakers and exhibitors) attended.

The CIBSE Natural Ventilation Group hosted a technical session covering the evaluation and practical implementation of natural ventilation. The objective was to provide up to date information on design methods based on water bath, wind tunnel and mathematical models. Presentations included several case study examples. In addition a session on environmental and air quality assessment issues covered practical solutions to prediction uncertainty, pollutant mitigation methods and overheating assessment.

This NVG session was well attended. Overall feedback from attendees was good and there was strong demand for future technical events to provide more guidance on natural ventilation, hybrid ventilation, simulation techniques, case studies, acoustics and indoor air quality.

The NVG Session presentations will be loaded on to the NVG Website.

Dr Martin Liddament
Chairman
CIBSE NVG Group

The Evaluation and Practical Implementation of Natural Ventilation - CIBSE Build2Perform Technical Session Report

Martin Liddament NVG Chairman

The CIBSE Natural Ventilation Group

The CIBSE Natural Ventilation Group is a large, international group, that was founded in 1994. The committee comprise some 55 members serving a wider membership of over 10,000.

Group Aims

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.

Committee Officers

Dr. Martin Liddament (Chair)
Professor Malcolm Cook (Vice-Chair)
Loughborough University
Dr. Vivian Dorizas (Secretary)
BPIE Brussels

Introduction

The success of a naturally ventilated building is dependent on good design. This includes optimizing the location and sizing of ventilation openings combined with a control approach that responds to the varying driving forces of wind and temperature. Such design requires knowledge about the aerodynamic performance of ventilation openings and the magnitude and variation of natural driving forces. Natural ventilation must also be effective in meeting occupants' needs for thermal comfort, health and good indoor air quality. These topics were presented in three sessions covering assessment methods, mathematical modelling and environmental assessment issues. This session was chaired by Dr Ben Jones, assistant professor at the University Nottingham (UK).

Session 1. Assessment Methods

Principles of Water Bath Modelling
Dr Shaun Fitzgerald

Dr Shaun Fitzgerald (Royal Academy of Engineering Visiting Professor at Cambridge University and CEO Breathing Buildings) introduced the first session by asking which way does the air flow? He demonstrated how water bath methods have been successfully used in ventilation design to assess airflow patterns, especially in situations where there are multiple interconnected openings. Advantages of water bath modelling include helping to visualise 3D flows and reducing the challenge in interpreting results. Successful interpretation requires understanding of the dynamic similarity between water flows in experiments and air flows in buildings. He explained that whilst it

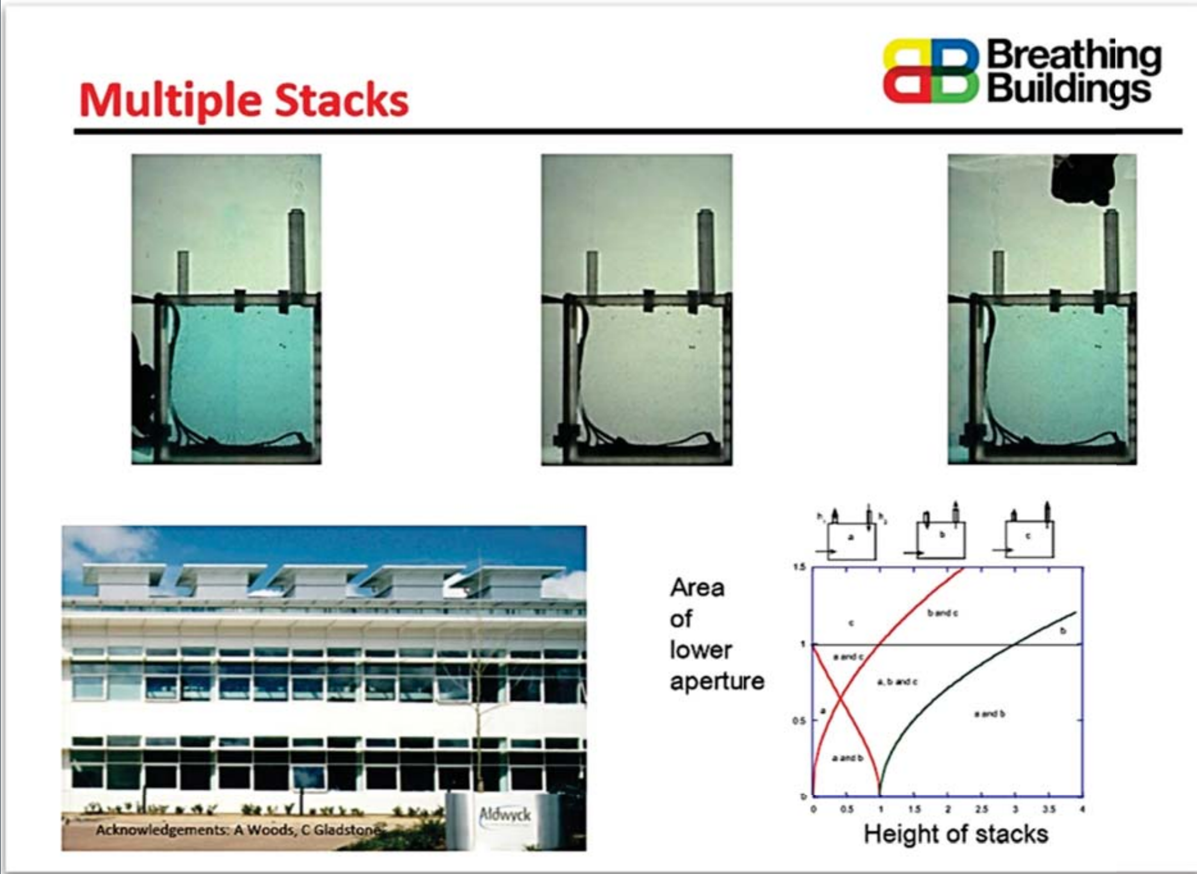

Figure 1. Using the water bath method to analyse airflow through multiple connected openings.

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is not possible to have dynamic similarity for all dimensionless groups, the experiments are extremely powerful and are often used to complement other modelling techniques such as computational fluid dynamics.

A particular problem that can be rapidly demonstrated with the water bath technique is the transient nature of airflow in which more than one stable airflow pattern can evolve for identical boundary conditions (Figure 1). It is also possible for a solution to include bi-directional flow and a natural oscillation of flow direction over time.

In summing up Shaun emphasised that it was important to understand flow patterns and their impact. Potential issues either needed to be accepted or designed out. Water bath methods could quickly assess a variety of configurations that would be difficult using numerical computational fluid dynamic (CFD) techniques.

Wind Tunnel Modelling for Natural Ventilation Design - Dr David Hamlyn

Dr David Hamlyn (RWDI) described how wind tunnel modelling provides essential information for the siting and sizing of openings as well as the assessment of airflow patterns and thermal performance. An accurate analysis of wind pressure is essential in assessing the impact of wind induced natural ventilation. In numerical modelling studies this is largely input via wind pressure coefficients. Without a wind tunnel study, default values of wind pressure coefficient are commonly used that tend to provide face averaged values for a limited range of building shapes and exposures. The building and surrounding geometry of a real development are different to default conditions thus making accurate desktop prediction of wind pressures difficult. Since wind tunnel studies focus on scale models of actual building configurations such studies provide much improved data including identifying localised problems and the impact of wind fluctuations. These results may be used for accurate ventilation design and risk assessment.

Correlating wind speed and direction with climate variables allows the risk of under-ventilation or overheating to be examined. Combining wind pressure information with the details of the vent design can help analyse the potential for localised draughtiness and improve resilience to

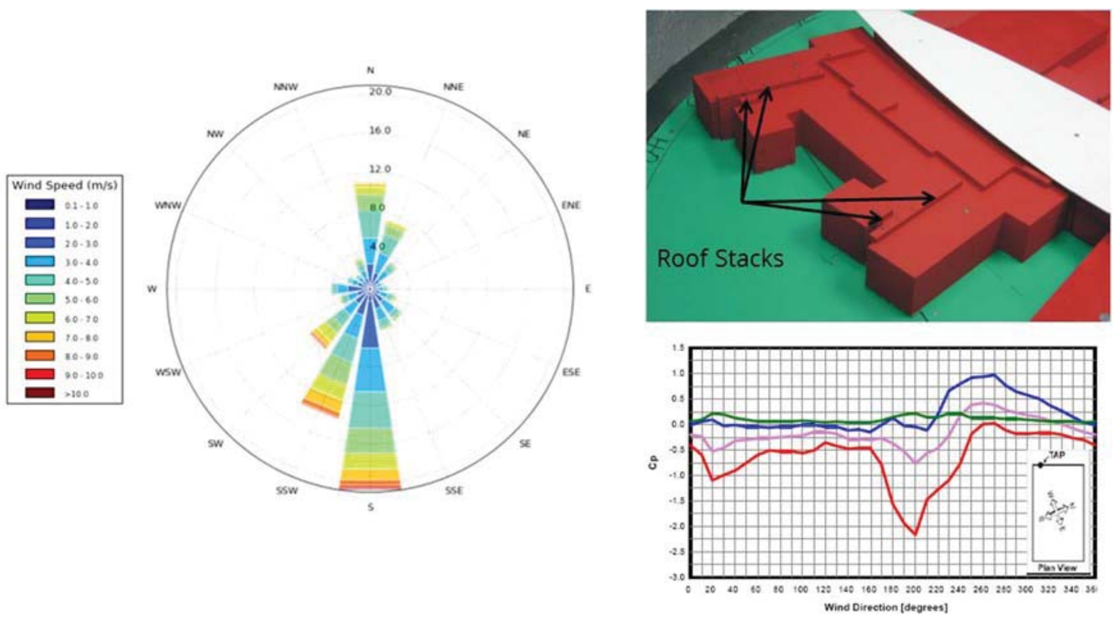


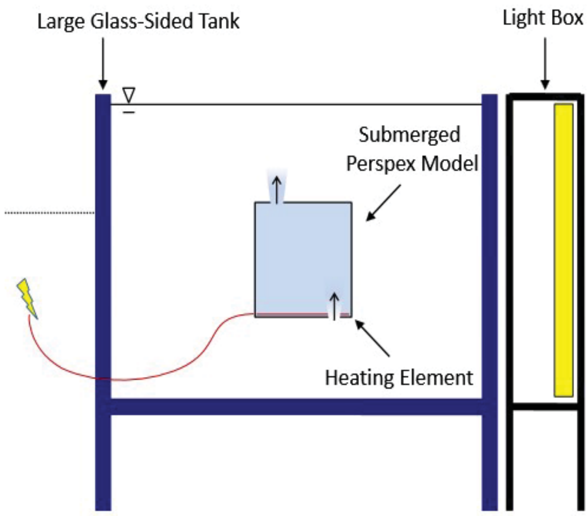
Figure 2. Analysis of pressure coefficients in relation to wind speed and gustiness provides information to improve resilience in design.

fluctuations in wind speed and direction (Figure 2). Wind tunnel data can be used as data input to internal CFD and Zonal airflow models to substantially improve the accuracy of ventilation simulations.

Assessment Methods and Modelling of Natural Ventilation "Life in a fish tank"
Dr Owen Connick

Dr Owen Connick (Breathing Buildings) extended the discussion on water bath modelling. The water bath method enables flow patterns to be visualised at the design stage (Figure 3). In the case of buoyancy conditions a perspex scale model is inserted into a water tank. Buoyancy is generated either by using a heated element or by using a salt solution of different density to represent the buoyancy condition. A dye is used to visualise the flow pattern. In the case of wind driven conditions or combined wind and buoyancy the model is inserted into a flume of flowing water. These principles were highlighted by considering an atrium case study.

Very often the perceived flow path developed at the architectural stage differs from practice. A water bath model representing part of an atrium building was used, in conjunction with a CFD analysis, to assess potential airflow and overheating risks (Figure 3).



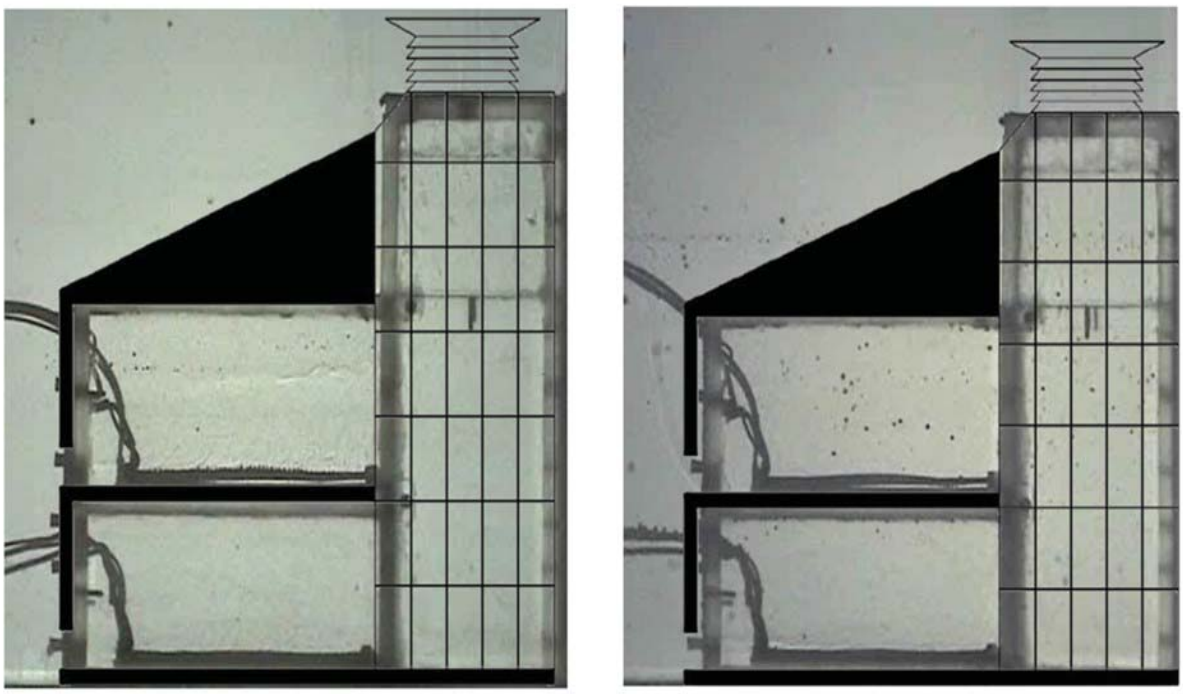


Figure 3. Flow pattern from water bath modelling used to assess flow pattern and potential over heating risk.

Hybrid and natural ventilation in practice … what are the experiences?

Jannick K. Roth

Jannick K. Roth (WindowMaster) considered the implementation of hybrid and natural ventilation in practice by outlining successful natural and mixed mode ventilated buildings in several countries including the UK, Denmark, Germany and the United States. Experts in these countries have individually produced design guides and many of these were listed. It was concluded that there would be much value in merging these into a single guide. This could be realised in the new technical specification dealing with "natural and hybrid ventilation systems" for non-residential buildings, which is currently under development.

Jannick stressed that for a successful ventilation design it was important that the approach was properly designed and engineered so that it took account of the full range of driving conditions and occupant needs. Secondly the system needs to be controllable and should interact with associated systems including mechanical systems, smoke ventilation, heating and cooling systems, solar shading and smoke ventilation (Figure 4). Thirdly the system needed to be commissioned and that customer support must be provided. Above all teamwork is required involving interaction between architects, building owner, and manufacturer.

Session Summary

In summing up the session questions were raised about the cost of water bath techniques and choosing between hot wire and salt as the thermal source. Costs were estimated at between £5k – 10k depending on complexity. Saline solution was recommended as most appropriate for representing point sources such as for fire or smoke modelling.

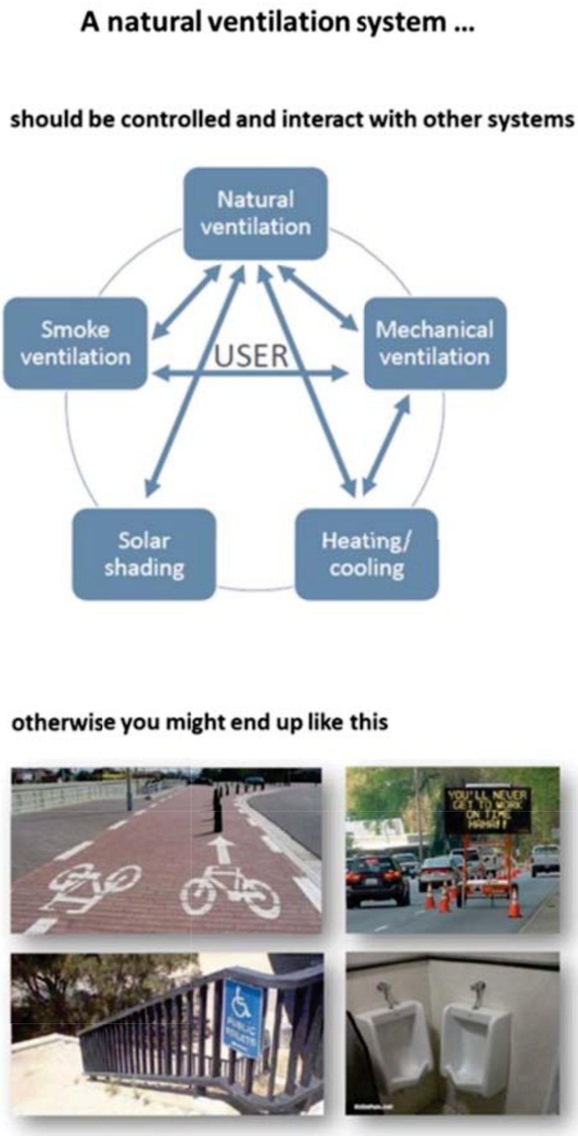


Figure 4. Designing to interact with other systems.

Session 2. Mathematical Modelling

Mathematical modelling is essential for almost any design work. This session presented recent developments in numerical simulation techniques for natural ventilation.

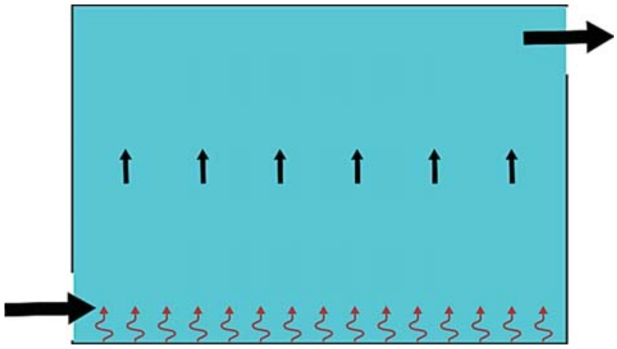
Modelling Localised Airflows within Rooms

Dr Henry Burridge

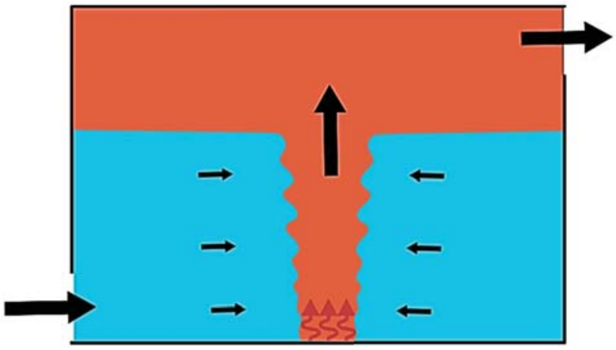
Henry Burridge (Imperial College) considered the modelling of localised air flows in rooms generated from many sources including the natural flow, fans, diffusers and heaters (Figure 5). BMS systems are increasingly capable of predicting and responding to thermal comfort, air quality and energy consumption. However, to run predictively and asses uncertainty these systems would require models than can run quickly.

Systems can give rise to localised high velocity flows that can influence comfort, ventilation rate and air quality exposure levels. In practice the nature of heating and cooling, not just the amount, determines occupant experience. An example was illustrated in the presentation in which a 1kW heat source in a simple room was applied via a uniformly heated floor, a local heat source and a fan heater. Each produced a different outcome. In the case of a heated floor (Figure 5a), temperature is uniformly distributed throughout the space. A weak a circulation is established and IAQ pollutant sources are advected upwards with mild dispersion. By contrast, a local source (Figure 5b) produces a warm plume resulting in a cool lower layer and a hot upper layer. IAQ pollutants are advected into the plume and upwards but thermal comfort may be poor and energy inefficiently used. In the case of a floor level fan heater (Figure 5c) a significant circulation is established. Temperature and pollutants are relatively uniformly distributed throughout the room but the residence times of pollutants might increase. Thus the same heat input gives different thermal outcomes and IAQ exposure. Simple parameterisations of these canonical cases offer fast models which could be run predictively by a BMS.

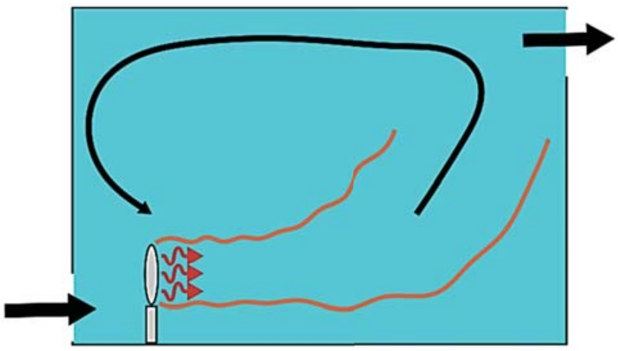
In developing building management systems there are several environmental challenges including establishing a sufficient monitoring network, characterising thermal sources of local flows, identifying interactions of local flows and determining the coupling of rooms via air exchanges.



(a) heated floor.



(b) Local source.



(c) Fan heater.

Figure 5. Air flow patterns for different 1kW heat sources.

Henry concluded that modelling local airflows offers great scope for better thermal comfort, air quality and reduced energy consumption. However despite progress there are plenty of challenges still for research and practice.

Mathematical Modelling Techniques for Natural Ventilation - Prof Malcolm Cook

Professor Malcolm Cook (Loughborough University) reviewed mathematical modelling techniques for natural ventilation and illustrated his presentation with a number of case studies. Techniques range from simple rule of thumb and analytical methods to zonal network models and computational fluid dynamics (CFD). Zonal models may also be connected to dynamic thermal simulation (DTS) models.

While rules of thumb and analytical solutions can provide some basic guidance without the need for much data, network and CFD methods are necessary for in depth design analysis. Network systems are used to determine hourly average values of air, pollutant and heat flow between individual zones (normally rooms) as well as between indoors and outdoors. DTS network models lend themselves well to whole building analysis and are ideally suited for investigating transient effects such as varying wind and buoyancy conditions. Results can also be used for determining boundary conditions for CFD. Limitations include the assumption that each zone is well mixed, wind coefficient data are limited, single sided ventilation is simplified and that the network is insensitive to shape (e.g. distribution of heat gains and opening positions within each zone).

CFD methods are used to resolve airflow, pollutant and thermal distribution conditions within individual zones (Figure 6). This is a complex technique requiring experience and knowledge to obtain reliable solutions. Challenges include incorporating buoyancy-driven flows, turbulence modelling and setting boundary conditions at openings. Getting a converged solution can be difficult. Also hardware limitations make whole building analysis impractical and transient flow analysis difficult. In addition, licensing costs for commercial codes are costly. However, notwithstanding these challenges, CFD is potentially very accurate. It is able to predict spatial information (e.g. thermal stratification) giving values for variables at many locations throughout the flow domain. It is also easy to investigate changes in geometry and operating conditions.

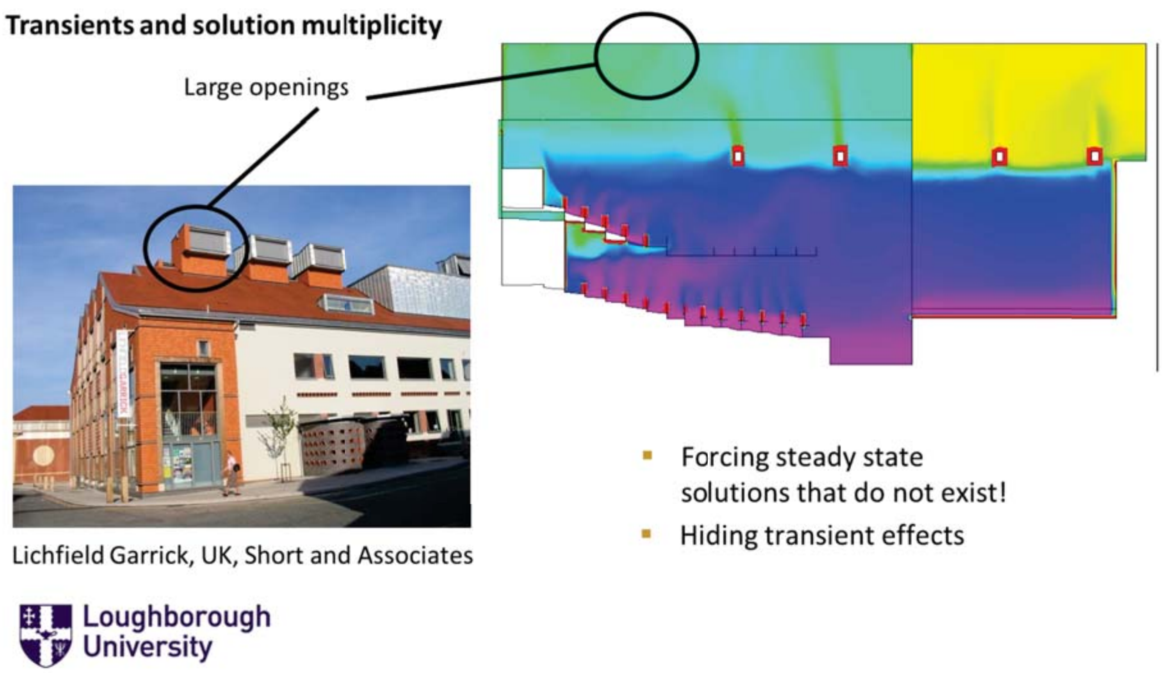


Figure 6. CFD modelling of airflow and thermal conditions in a theatre.

Additional models (e.g. pollutant transport) can be added with relative ease. CFD results are visually impressive and perceptible. Malcolm warned against the dangers of forcing steady state solutions which may not exist, and the benefits of transient simulations which recent advances in hardware power make possible.

An overview of ventilation opening area terminology and how to estimate window effective areas in the absence of manufacturer data - Dr Chris Iddon

Dr Chris Iddon (SE Controls) presented an overview of ventilation opening area terminology and how to estimate window effective areas in the absence of manufacturer data. There is currently widespread confusion over terms used to describe the geometry of ventilation openings and hence this has become an important topic. Examples were presented for:

- Openable windows;
- Louvres;
- Complex vents with convoluted airflow paths.

Essentially calculations must take into account the effective area of an opening rather than its free area. The effective area is a function of the aerodynamic discharge coefficient (Cd) of the opening which, itself, is dependent on the physical opening characteristics of the component and the opening angle. In addition components with convoluted airflow paths are often expressed in terms of an equivalent area in which the free area is represented by the area of a circular orifice giving equal flow characteristics:

$$A_{eq} = \frac{C_d A_f}{C_{d_o}} = \frac{A_{eff}}{C_{d_o}}$$

where A_{eq} = equivalent area, A_{eff} = effective area, A_f = free area, C_d = coefficient of discharge, C_{d_o} is the coefficient of discharge of a circular orifice, typically 0.61.

All these parameters are difficult to measure or evaluate making reliable inputs to numerical calculations difficult. Even determining the free area can be problematic. Some window system companies have measured Cd values which can be used to estimate the effective area of a vent where:

$$A_{eff} = A_f C_d$$

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$$A_{eff} = A_f C_d$$

Where Af is the geometric throat area of the window *w x h*.

The Cd is derived experimentally using the method in BS EN13141-1:2004 where the vent is placed in isolation and flush with the façade of the test box. In reality the window may be placed in a façade with deep cills or reveals which will impact the air flow through the vent and therefore using the derived Cd values is likely to over-estimate the effective area of the window in situ.

An alternative rule of thumb methodology is to use a fixed Cd value and to measure the free area as the sum of the "rectangle and triangles" formed by the opening sash, as the opening angle increases the free area increases proportionally:

$$A_{eff} = A_f C_d$$

Where Af is the minimum of the geometric throat area of the window and the sum of the rectangle and triangle: *(w x s)* + *(h x s)*

w = width, *h*= height, *s* = stroke length

Figure 7 presents example estimates of the Effective Area of an openable window using both the derived Cd method and the rule of thumb (RoT) method, which give similar results, however using the RoT it is possible to account for reveals, for example the blue line on the graph assumes very deep reveals that obstruct airflow through the triangles and the triangular portion of the RoT Af calculation are assumed to be zero. This demonstrates the differences in Aeff that could be realised using the two methodologies and how the RoT can perhaps better estimate the Aeff where building construction elements may impede airflow. It should be noted that to date we have not been able to conduct the necessary experiments to establish the efficacy of the RoT methodology, more research is required.

Session 3 Environmental and Air Quality Assessment Issues

Uncertainty about ventilation rates, thermal climate and pollution emissions can result in poor energy performance, over heating or cooling and poor indoor air quality. These issues were covered in this session.

Uncertainty in Predictions of Airflow Rate Dr Ben Jones

Dr Ben Jones (Nottingham University) made a presentation on the uncertainty in predictions of air change rate. Data needed to calculate natural ventilation rates is notoriously uncertain, especially when considering infiltration through cracks and gaps in the building. As a starting, point Ben considered the basic assumptions related to energy use in UK homes which is estimated at greater than 25% of total UK energy demand and CO_2 emissions. Winter

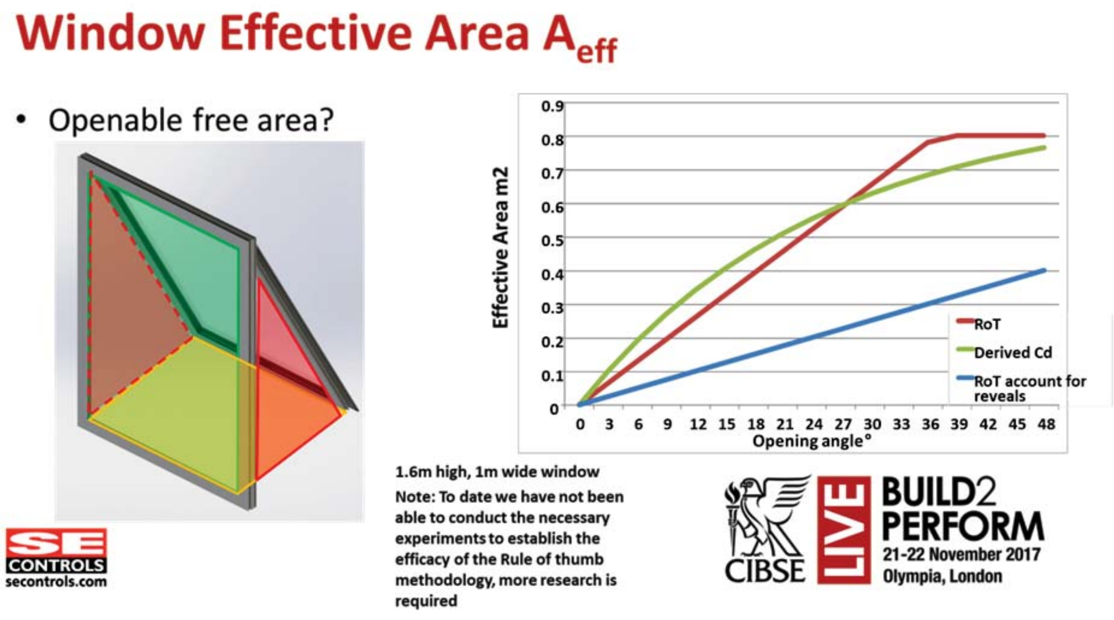

Figure 7. Calculated window effective area of openable window based on 'rule of thumb' (RoT) and derived Cd.

exfiltration is thought to be a significant contributor but is it? Where is the evidence? There have been no large scale measurements of air infiltration and yet policy is based on the assumption that air infiltration is a significant problem. From the research point of view the question raised is what is the uncertainty of the mean infiltration rate of UK houses during the heating season and what is the associated energy demand and CO_2 emissions? How can this be modelled? he proposed method to evaluate infiltration impact incorporates the following steps:

1. Data on houses using the English Housing Survey, a statistically representative survey of the English housing stock.

2. Apply a model of infiltration & exfiltration. DOMVENT was selected since this model specifically calculates infiltration assuming a uniform distribution of permeability for each face.

3. Represent each dwelling as a single zone, which are the same conditions experienced during a blower door test. The Cambridge Housing Model is used to form a cuboid model of each house.

4. Select distributions of data for each input into DOMVENT to describe the geometries and environments of houses.

5. Select a method of choosing random inputs for DOMVENT.

6. Select a method that shows when enough simulations have been made.

7. Test model sensitivity to identify the influences of bad data or guesses.

Some aspects of the data input is lacking in confidence including permeability of the party walls and indoor air temperature. Others are guessed such as permeable area, orientation and the aspect ratio of terraces. The problem is what if the model is sensitive

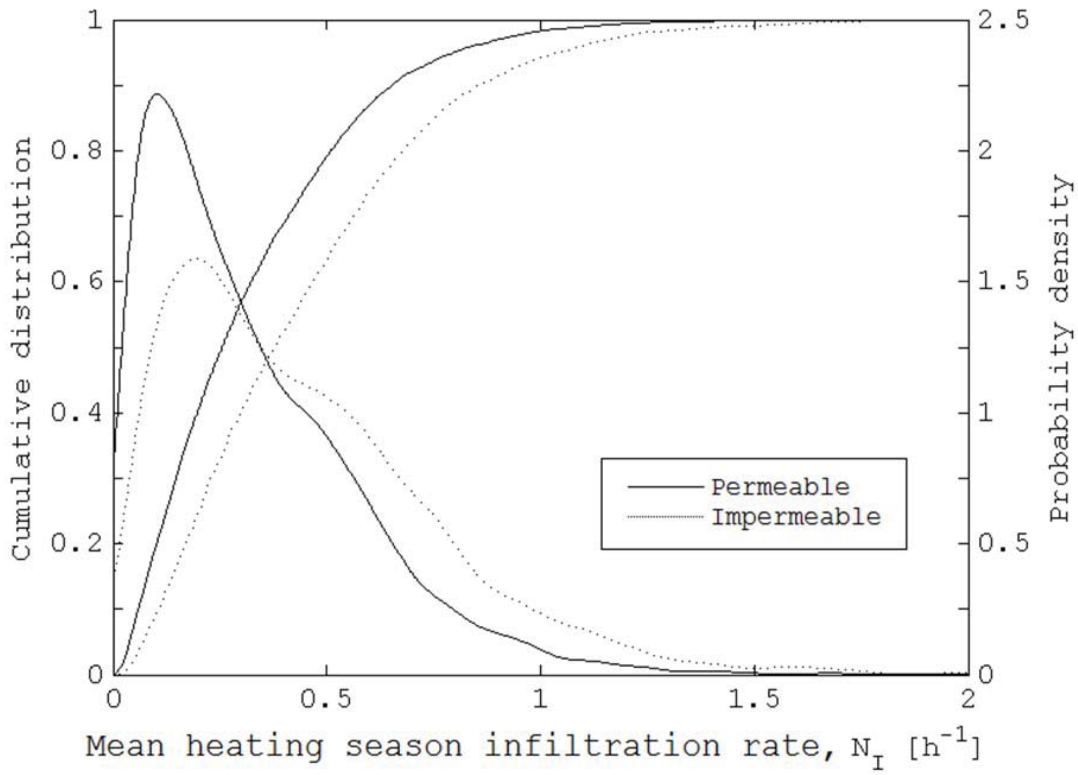

Figure 8. Predicted cumulative distribution of infiltration rate throughout the heating season.

to these uncertain inputs? To investigate these uncertainties the Monte Carlo approach was used. This relies on the sampling of data from probability density functions which is then inputted into the model and simulated to obtain a numerical result. This process is repeated multiple times, each time with different inputs. This results in many different outputs that can be reported as a histogram and a probability density function. These tools can then be used to show uncertainty in predictions. However, it is not possible to know just how many simulations are required and a decision has to be made at run time. Results are illustrated in Figure 8. If it is assumed that a dwelling needs an air change rate of $0.5h^{-1}$ then this graph shows that approximately 79% of dwellings are too airtight and require extra ventilation. This also shows the predicted cumulative distribution of infiltration rate throughout the heating season for dwellings with and without impermeable party walls. Using this infiltration data and applying it to the whole UK housing stock, air infiltration is estimated to account for 3-5% of UK national energy demand and 10-13.5% of the UK housing stock's CO_2 emissions.

Assessment of Indoor Air Quality from both Outdoor and Indoor Sources Stuart Upton and Dr Vina Kukadia Stuart Upton (BRE)

Stuart Upton (BRE) made a presentation on the assessment of indoor air quality from both outdoor and indoor pollution sources. He began by asking the question: why is indoor air quality important? In reply he stated that we spend on average 80-90% our time indoors and some spend up to 100% of time indoors (e.g. infants, elderly, infirm). Poor quality indoor air can have an adverse impact on health, comfort and wellbeing, performance and productivity, accuracy in performing tasks, learning ability, increased sick leave, healing and recuperation. Buildings and materials can also be damaged such as through condensation and mould growth.

Indoor air quality is affected by many pollutants from both indoor and outdoor sources. Reducing exposure to air pollution requires an integrated approach, including controlling indoor and outdoor sources and the provision of effective ventilation (Figure 9). For both outdoor and indoor sources, the

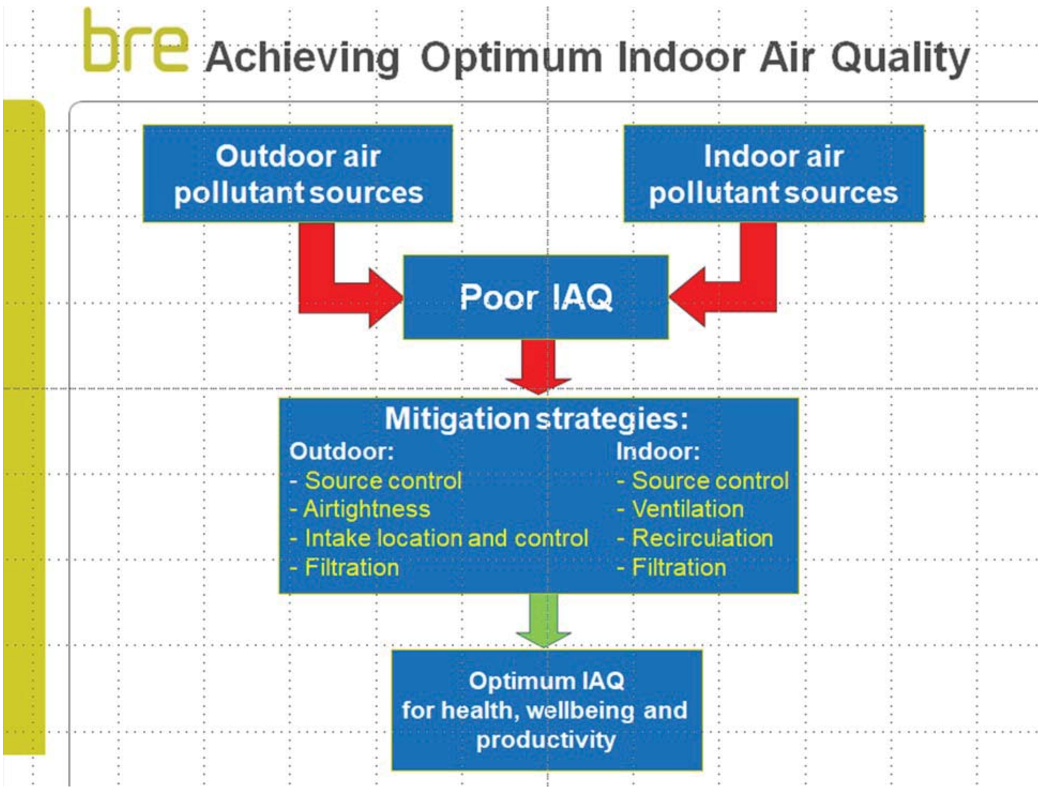

Figure 9. A methodology for achieving optimum indoor air quality.

primary mitigation approach is to identify harmful sources and suppress or eliminate them. Further measures to prevent the ingress of outdoor pollutants include ensurin good building airtightness, locating fresh air intakes away from local sources and, if necessary, using a filtration system targeting identified pollutants. Pollution from unavoidable indoor sources are diluted and removed by ventilation. In some circumstances the recirculation of air through a filtration system can provide a further reduction in concentration while avoiding high air ventilation rates.

Monitoring air pollution requires a variety of methods for measuring different types of pollutant. Careful selection and understanding of the pollutant to be monitored and the characteristics of the equipment used is necessary. Types of monitoring equipment and methods for particle and gaseous pollutants were described.

In summary it was concluded that providing good air quality is increasingly important for human health, wellbeing and productivity. Reducing exposure to air pollution requires an integrated approach, including controlling indoor and outdoor sources and the provision of effective ventilation to give optimum results. Monitoring air pollution requires a variety of methods for measuring different types of pollutant. In order to select the correct monitoring method a good understanding of the pollutant or pollutants to be monitored is required.

Characteristics of Design Summer Year Weather Files - Dane Virk

Dane Virk (Atkins) made a presentation on the characteristics of the CIBSE design summer year weather files. This was concerned with assessing the risk of summer overheating in buildings. CIBSE offer two types of weather data for design calculations. These are Test Reference Years (TRY) and Design Summer Years (DSY). For overheating assessment, probabilistic Design Summer Years (pDSYs) now exist for all CIBSE Weather file locations across the UK. Various definitions are used to define the duration and intensity of hot events. These include 'events' which is a continuous period where at least one hour a day goes above a threshold temperature; 'intensity' the total of the metric divided by the number of days of the event and 'return period' which is the frequency of the event associated with a given exceedance value. Design Summer

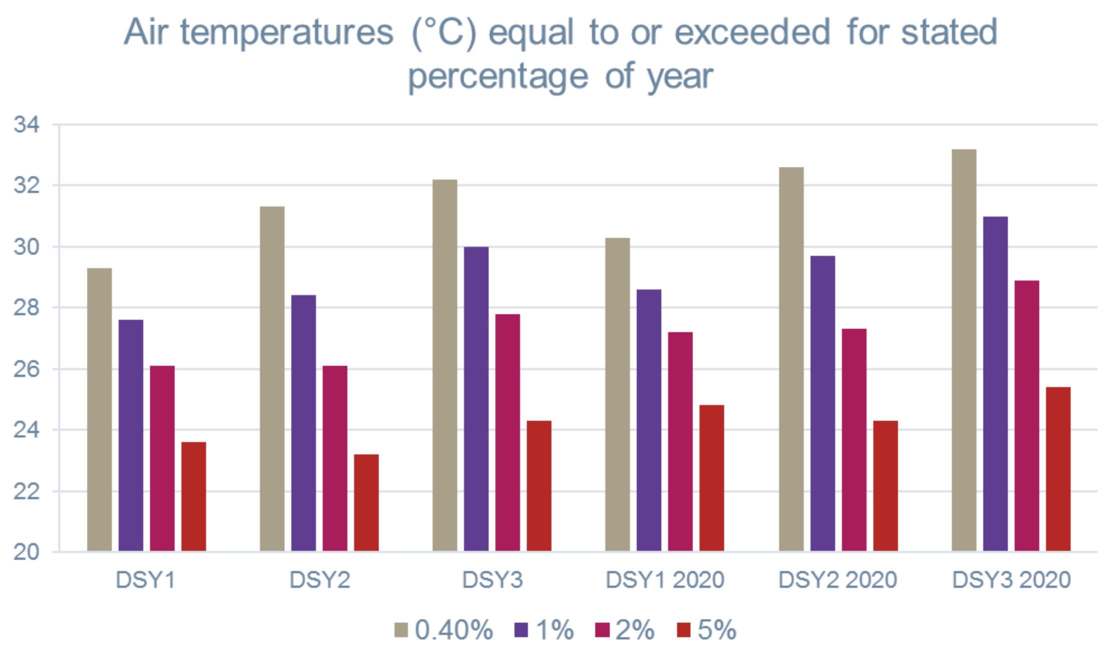

Figure 10. Comparison of near-extreme air temperatures for the DSY for London Heathrow.

Years are defined as: DSY1 moderately warm summer, DSY2 short intense warm spell and DSY3 long but less intense warm spells. DSY2 and DSY3 represent more extreme events. Future weather files based on climate predictions for the 2020's, 2050's and 2080's have also been produced. Comparison of these definitions for current and the 2020's, based on the Heathrow dataset, is illustrated in Figure 10. Examples of the use of weather data files and associated modelling methods to calculate overheating risk were outlined. These were based on the application of methods given in CIBSE TM52 "The limits of thermal comfort: avoiding overheating in European buildings and Design methodology for the assessment of overheating risk in homes" and TM59 "Design methodology for the assessment of overheating risks in homes".

It was concluded that TM52 and TM59 provided useful tools for risk assessment in response to changing occupancy patterns and vulnerable occupants. However DSY's and building simulation have their limitations, especially in assessing overheating risks in real buildings.

Session Summary

Following the presentations a question was raised about the selection of weather files. Was it possible to use a single file? In response Dane Virk said that it was not possible to make a single recommendation but it would be necessary to work through guidance given by CIBSE in TM52.

Stuart Upton was asked if, taking in account poor outdoor air quality, it is still possible to naturally ventilate buildings in London? He responded that it would depend on local conditions. In highly polluted areas it might not be recommended but a risk assessment would be required.

Forthcoming Events

Building Simulation and Optimization 2018
Emmanuel College, University of Cambridge, 11-12 September 2018

Building Simulation and Optimization (BSO) conference provides a forum for the exchange of knowledge on the development and application of building performance simulation to optimum design and operation of buildings.

The main conference themes are:

- New building performance simulation methods (e.g., energy, comfort, daylighting, airflow, air quality)
- New approaches for optimizing design and operation
- New decision support methods for real world applications (e.g., design, compliance, commissioning, predictive control, retrofit)
- Advances in model calibration, uncertainty analysis, and validation methods
- Occupant behaviour modelling
- Urban- and district-scale simulation of energy and environment
- Innovative applications of simulation in practice

The conference will take place on Tuesday and Wednesday with the conference dinner on Tuesday evening. A walking tour of Cambridge, with entry into one of the Cambridge Colleges will take place on Monday afternoon.

Full Details:
https://www.bso2018.event.cam.ac.uk

Build2Perform Live
27 - 28 November 2018
Olympia, London

The CIBSE Natural Ventilation Group plans to contribute to the next Build2Perform Live event.

Full Details:
http://www.build2perform.co.uk/