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Setting an example

It is always a challenge for designers to balance energy, indoor environmental quality (IEQ) and acoustic performance when designing schools. This especially held true at Trumpington Community College, where open teaching spaces overlook a large, airy atrium, so noise travelling between them was a potential issue. Using its SoundSpace laboratory, Max Fordham demonstrated to the client how important acoustic absorption would be, and this spared it from being value-engineered out (page 6).

A holistic approach to the design and operation of buildings is also imperative to ensure energy efficiency is not achieved at the expense of IEQ and other aspects of school building performance. Authors on page 12 argue that having operational performance targets underpinned by the Soft Landings framework or a performance contract can help designers, contractors and building managers improve a building's operational performance.

But, as researchers maintain on page 20, indoor environment and air quality standards must focus on volatile organic compounds – emitted from building materials and consumer products – not just CO_2, to help protect young people in educational buildings.

LIZA YOUNG, DEPUTY EDITOR lyoung@cibsejournal.com

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Learning best practice

The quality of educational facilities has a substantial impact on the experience, wellbeing and even health of students and staff. The role that building services play in this should not be overlooked.

There are a wide range of factors to consider when designing, installing, repairing or upgrading the heating and water systems within a school, college or university. These include considerations that are of particular importance in such environments, including the need to avoid unexpected expenditure on repairs when budgets are already under pressure. Any failure of the system means the building has to be closed, disrupting the learning of students. Also, the use pattern of these buildings – intense use during term time with long vacant stretches – is a key part of the challenge.

Careful consideration of the products used, both in the original design and for repairs and upgrades to the pipework, can help create a durable, reliable system and reduce whole-life costs for building managers. High-quality, modern press-connection systems offer a quick, reliable, clean and safe option for heating, hot and cold water and drinking water, as well as other applications such as compressed air and technical gases. Furthermore, the enhanced durability of a thick-walled steel tube means it continues to be the preferred option in many public sector buildings. Recent innovations allow press-connection technology to be used on even large-diameter thick-walled tubing, making installation quicker and delivering greater consistency.

It is important that staff and students are able to use their facilities fully and focus on what is important. This means the smooth running of all buildings is critical, and reliable building systems form a core part of this.

SCOTT JAMES, director at Viega
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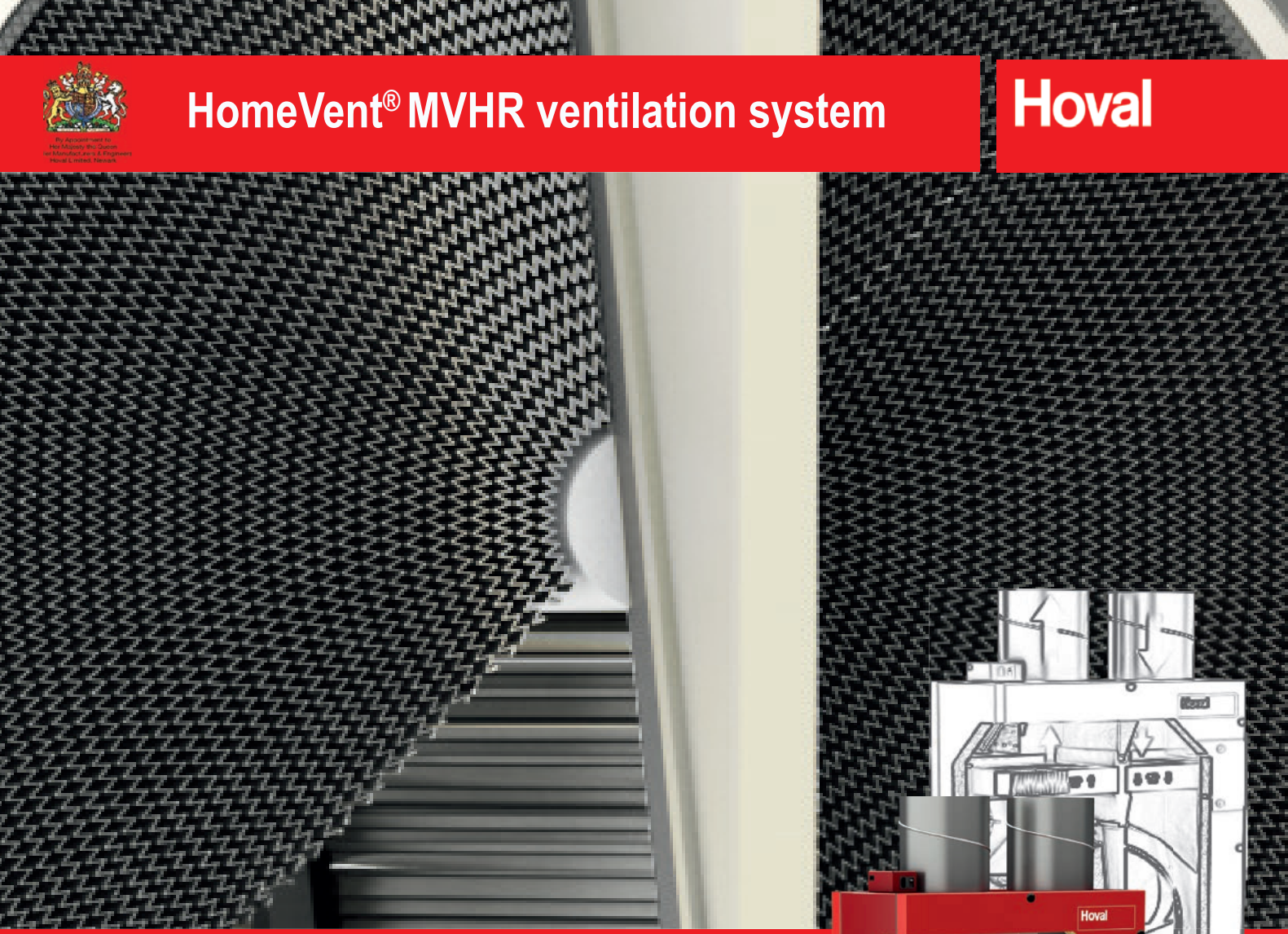

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Responsibility for energy and environment

Why school buildings have to pass the resilience test

The CIBSE School Design Group has formed a working group to investigate the impact of longer-term climate change projections on new and existing schools. Faithful+Gould's Tim Taylor introduces the key issues

The message on climate mitigation is clear – drastic cuts are needed to the greenhouse gas emissions caused by human activity. A challenge for the construction sector is how to implement this while safeguarding buildings and infrastructure to the predicted changes in climate 'locked in' by historic emissions. So what are the risks to the UK's buildings and infrastructure, and are we prepared?

In December 2018, the Met Office published its latest projections of the changes expected in the UK's climate up to 2100. The data was accompanied by the message that 2018's record-breaking summer will become more like the norm.

The increased risk from heat has led Public Health England to produce a new Heatwave Plan for England. However, the Committee on Climate Change has warned that more action is needed to address the risks to public health and wellbeing from high temperatures, with its latest report on the future of UK housing identifying current overheating policy as 'inadequate'. The Ministry of Housing, Communities and Local Government recently announced plans to consult on a method for reducing overheating risk in Building Regulations.

"The range of school building typologies means there can be no 'one size fits all' approach"

For schools, the methodology for assessing overheating risk was updated in the latest edition of BB101.[1] This brings design guidance in line with current industry practice, referencing CIBSE TM52 and CIBSE future weather files. Breeam has updated its methodology under the 'Design for future thermal comfort' criteria in the new 2018 scheme.

The CIBSE School Design Group has established the Climate Change Adaptation of Schools working to look at the climate resilience of schools. It will investigate:

- What climate resilience looks like for schools under climate scenarios, from 2020 to 2010
- What must happen to make adaptation planning business as usual.

The working group will share knowledge, where the differing drivers of the industry-wide organisations are recognised, while building a collaborative and balanced range of recommendations to which industry can respond.

The objectives of adaptation are interlinked with those of mitigation – so buildings that are climate resilient must also be low or zero carbon, as well as healthy places. Geographical variations in climate change impacts, and the range of school building typologies, mean there can be no 'one size fits all' approach to adaptation. A robust evidence base is needed to offer a foundation for future design choices to reduce risk – starting with cost-effective measures first.

This implies priority be given to passive design measures, such as building form, organisation of internal spaces, massing, and orientation of the building on the site to control solar gains. At the same time, there must be recognition of the cross-section of the building (diagram below) to create a healthy indoor environment with adequate ventilation and daylight.

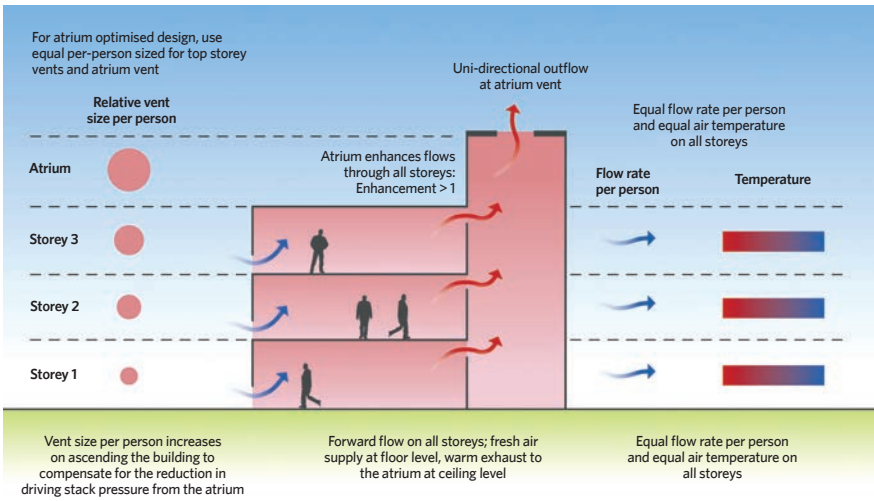
Having optimised the passive design measures, the most appropriate response will be shaped by the building context – its construction, location, whether it's an existing building or new-build – and the life-cycle costs to the school.

The work will be informed by insights gained from thermal modelling and monitoring of existing schools, as well as previous research, such as the 'Design for Future Climate' and 'Building Performance Evaluation' competitions funded by Innovate UK.

References:

1 BB101 *Ventilation for school buildings*, Department for Education, August 2018 **bit.ly/2ucFVvM**

TIM TAYLOR is a member of the CIBSE Schools Design Group and senior consultant at Faithful+Gould, part of the SNC-Lavalin Group



Ideal design 'blueprint' for an atrium building, shown here for a three-storey building. Principle applies to any number of storeys (source: BB101).

Silent treatment

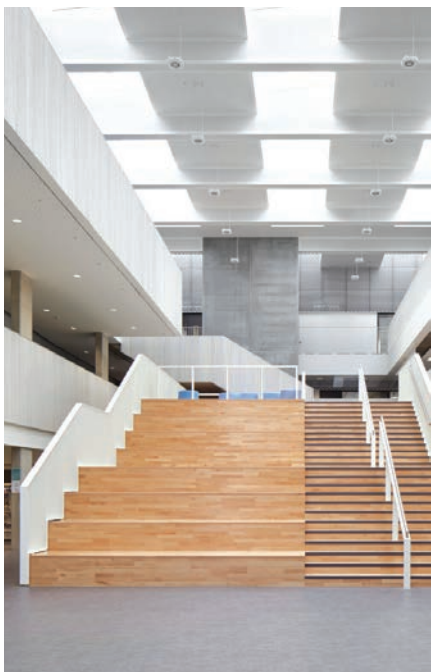
The design brief for Trumpington Community College was for open teaching spaces overlooking a large, airy atrium. The challenge for Max Fordham's acoustic engineers was ensuring teachers were not disturbed by noise from neighbouring spaces. Andy Pearson reports

The City of Cambridge Education Foundation is committed to human-scale education. It wanted its new secondary school for 750 students in Trumpington, Cambridge, to be designed to enable students to work alone, or in small or large collaborative groups, in spaces that allow for multiple, simultaneous student activities.

The foundation even took the design team, assembled to build the new facility, to Denmark to visit two schools that had been designed around a similar ethos, with open-plan learning to encourage pupil and staff interaction.

Avanti Architects' design for Trumpington Community College incorporates elements from the Danish schools, including a day-lit atrium; the school's entrance leads pupils directly into this triple-height space, the centrepiece of which is what the architect terms an 'over-sized' stair. This doubles as informal raked seating, while leading pupils up to two L-shaped teaching floors that wrap around the central void. The upper floors have classrooms at the outer perimeter while open-plan, informal teaching areas surround the atrium, to enable up to 250 students to be taught informally, at small tables, in clusters of two and three.

The school wanted open-plan spaces to facilitate multiple, simultaneous activities – but open-plan teaching has a bad reputation for noise issues. Max Fordham, the acoustic consultant for the project, was so concerned that background noise levels would significantly affect speech intelligibility that it used its SoundSpace laboratory to replicate – for the design team and teaching staff – the precise acoustic conditions that pupils would experience. It then used the laboratory to develop an appropriate solution.



'Our brief was to create comfortable study conditions in which students and teachers could communicate over short distances of up to approximately two metres,' explains Pedro Novo, acoustic engineer at Max Fordham. He says there are two main acoustic issues with open-plan space: control of direct sound coming from adjacent spaces and control of the reverberant sound, which arrives from all directions. 'Because the open-plan spaces are high, long and wide, these conditions occur in pretty much every space where teaching will take place,' he adds.

The performance standard for speech intelligibility in open-plan spaces is

All photographys Jack Hobhouse

The college wanted open-plan spaces for multiple, simultaneous activities

described by the Speech Transmission Index (STI), which Max Fordham used as the main acoustic design parameter for the open-plan spaces. It applies to speech transmitted from teacher to student, student to teacher, and student to student. The design aim was to achieve a high STI up to 2 metres from the source (for example, a teacher's voice) and a low STI at higher distances – 4 metres and above – to minimise disruption to neighbouring spaces. 'An important aspect of the Index is the background noise – which will change with the number of students and activities in the space – because the higher the background noise, the lower the speech intelligibility,' says Novo.

An activity plan, developed with the school, was used to establish the likely overall noise level resulting from teaching and pupils' activities in the open-plan space. Max Fordham used its computer prediction model (see panel, 'Sound advice') to calculate the STI, using the overall level of noise as the background noise level. It then used the SoundSpace to convey to the staff and project team the noise and speech intelligibility that would be experienced by the pupils.

After experiencing the noise environment virtually, in the auralisation demonstrations, it was clear that some form of acoustic treatment was required if the open-plan spaces were to be used effectively. To reduce the reverberation time, Max Fordham worked with Avanti Architects to add sound-absorbing materials to them.

'Having acoustic absorption installed near to noise sources is more effective than having the absorption installed far away, so that the noise is readily absorbed, rather than being allowed to bounce back »

"There are two main acoustic issues with open-plan space: control of direct sound from adjacent spaces and of reverberant sound from all directions"

» and forth between surfaces,' says Novo.

Max Fordham calculated that a minimum 2,000m^2 of acoustic absorption was required to absorb as much sound as possible and prevent noise buildup, while physical barriers were needed between adjacent working areas. 'Avanti Architects were extremely accommodating and creative in integrating this vast amount of acoustic absorption, and in designing 1.6m-high storage spaces between working areas,' says Novo.

A variety of acoustic-absorption measures were adopted. On the walls, some spaces are fitted with timber battens, behind which is 50mm of mineral wool. On other walls, metal mesh retains the mineral wool. Perforated plasterboard is employed in the corridors and on the ceilings, behind which is also mineral wool. 'Acoustic absorption results in reduced general noise levels, which, in turn, results in people speaking at lower sound levels – so there is a positive feedback loop when acoustic absorption is applied,' says Novo.

SOUND ADVICE

Virtual walk-throughs help users understand how spaces work in 3D. Now imagine going on a walk-through but with a soundtrack that mimics the precise noise levels at any point in that space.

This is what happens in the SoundSpace studio of engineer Max Fordham. The facility enables the consultant's clients to hear what the acoustics will sound like in a proposed space or in a modified existing space.

In the SoundSpace studio, the listener is surrounded by 14 loudspeakers, arranged as if mounted on the inner surface of a nominal sphere.

The starting point for the modelling is to import a computational model of the three-dimensional space into the acoustic simulation software. Acoustic properties are then assigned to each of the surfaces of the imported space.

A sound source is defined by attributing specific acoustic characteristics – including sound power levels and directivity – to simulate, say, a teacher's voice. Then the number and location of the sound receivers are defined, which might be a group of students sitting several metres from the teacher. The acoustic software then models that scenario to collect the sound arriving at each receiver. The calculation process uses ray-tracing algorithms, similar to those used for lighting calculations.

'The source fires rays, which represent a certain level of sound energy, and the software follows these rays as they hit the wall, with part of the energy absorbed and part reflected,' says acoustic engineer Pedro Novo.

'This continues until all of the ray's energy has been absorbed,' he adds. 'Receivers capture the amount of sound energy when it arrives at that particular point.'

The surrounding loudspeakers then replicate the sound. 'In the SoundSpace, the reproduced sound arriving to the listener from each of the 14 loudspeakers is the same as that which the listener would have experienced if they were located in the actual space,' says Novo.

The system can also be used for an existing building. Engineers first capture the sound experienced by the receiver using a microphone, which also captures the direction from where the sound is coming. Max Fordham then models the space – for example, to gauge the impact of various acoustic treatments.

Max Fordham's SoundSpace allows clients to hear what their building will sound like

Max Fordham also looked to the two Danish schools that had so impressed the foundation for acoustic-treatment design precedents. It found that their interiors incorporated acoustic wall and ceiling panels, and sound-absorbing treatment on the floor; however; it also recognised that the occupancy density is much lower in the two Danish schools, with each pupil having an average 9m^2 of floor space. In UK schools, the figure is closer to one pupil every 3m^2, so the acoustic treatments at Trumpington would need to work much harder than those in the schools in Denmark.

Using SoundSpace, various demonstrations were undertaken at different points of the design to show the effectiveness of the diverse acoustic solutions as they were developed. For example, Max Fordham used a demonstration to illustrate intelligibility at different distances. 'The review made clear that effective communication would be possible up to a maximum of 2 metres,' says Novo. »

Hi-fi specialist chooses ultra-quiet Toshiba system for high-end listening studio

Audio engineers at hi-fi specialist Sonority Design have installed an ultra-low noise R-32-based Toshiba air conditioning system to ensure the best possible listening environment for its customers.

TCUK is a joint venture between Toshiba and Carrier in the United Kingdom, and is part of Carrier, a leading global provider of innovative heating, ventilating and air conditioning (HVAC), refrigeration, fire, security and building automation technologies.

The Brierley Hill-based audio company concluded that Toshiba's bi-flow RAS console split system was one of the quietest available, with a sound pressure range of just 31-46dB(A), equivalent to a quiet bedroom in the dead-of-night and the hushed environment of a university study library.

Nigel Kuscher, managing director of Ref-Sol Limited, which installed the Toshiba system, said: "Our client specialises in very high-end hi-fi systems, which require the lowest possible ambient noise to preserve outstanding audio reproduction. They established that the Toshiba bi-flow system was one of the quietest available, and would deliver the comfortable environment needed for customers to audition equipment without detracting from the audio experience."

He added: "The other consideration was aesthetic design, in order to blend in with the up-market ambience of its retail outlet and listening studio. The discrete appearance and flowing curves of the Toshiba bi-flow console unit were a perfect match," said Kuscher.

The design of the Toshiba bi-flow system allows air discharge from the top and bottom of the unit, reducing turbulence and associated sound emissions while delivering excellent comfort conditions and energy efficiency.

It uses the latest digital hybrid inverter technology to precisely match output to demand, further reducing sound levels, and is equipped with a fine-filter system to ensure optimal indoor air quality.

The Sonority Design system delivers a total of 7.2kW of cooling and has an energy label rating of A++. Indoor units are Toshiba's console model RAS-B18UFV-E1, and the outdoor unit is model RA3M27S3AV-E.

For more information, visit www.toshiba-aircon.co.uk

MIKROFILL AT HOUNSLOW TOWN PRIMARY SCHOOL

With the need for more school places at an all-time high, a brand new five form entry school constructed by Jerram Falkus has been built in Hounslow, West London. The second phase of the build will include 284 mixed-tenure homes including affordable housing.

Building services consultants Baily Garner LLP delivered a fully designed M&E project which incorporated Mikrofill equipment. The schools LPHW/HWS demand was met by the selection of 3No Ethos FS 350 kW twin burner condensing boilers. Installed by long standing contractor R & H Building Services Ltd, the stainless steel boilers provide a collective turn down ratio of 60 > 1 (1050 > 17.5 kW), produce as little as 31mg/kw of Nox and can be installed as close as 50mm apart from one another.

The domestic hot water demand throughout this large primary school is catered for by 2 No Wras approved Extreme 500 litre loading cylinders. With a primary input of 120kW at 80°c, each cylinder can produce in excess of 2500 l/hr at 60°c. Installed with unvented kits the cylinders maximise the efficiency of the Ethos boilers by ensuring a Δt of 30°c on the primary circuit (80/50°C).

The existing school continued operation during the site redevelopment with the new school being occupied in September 2018.

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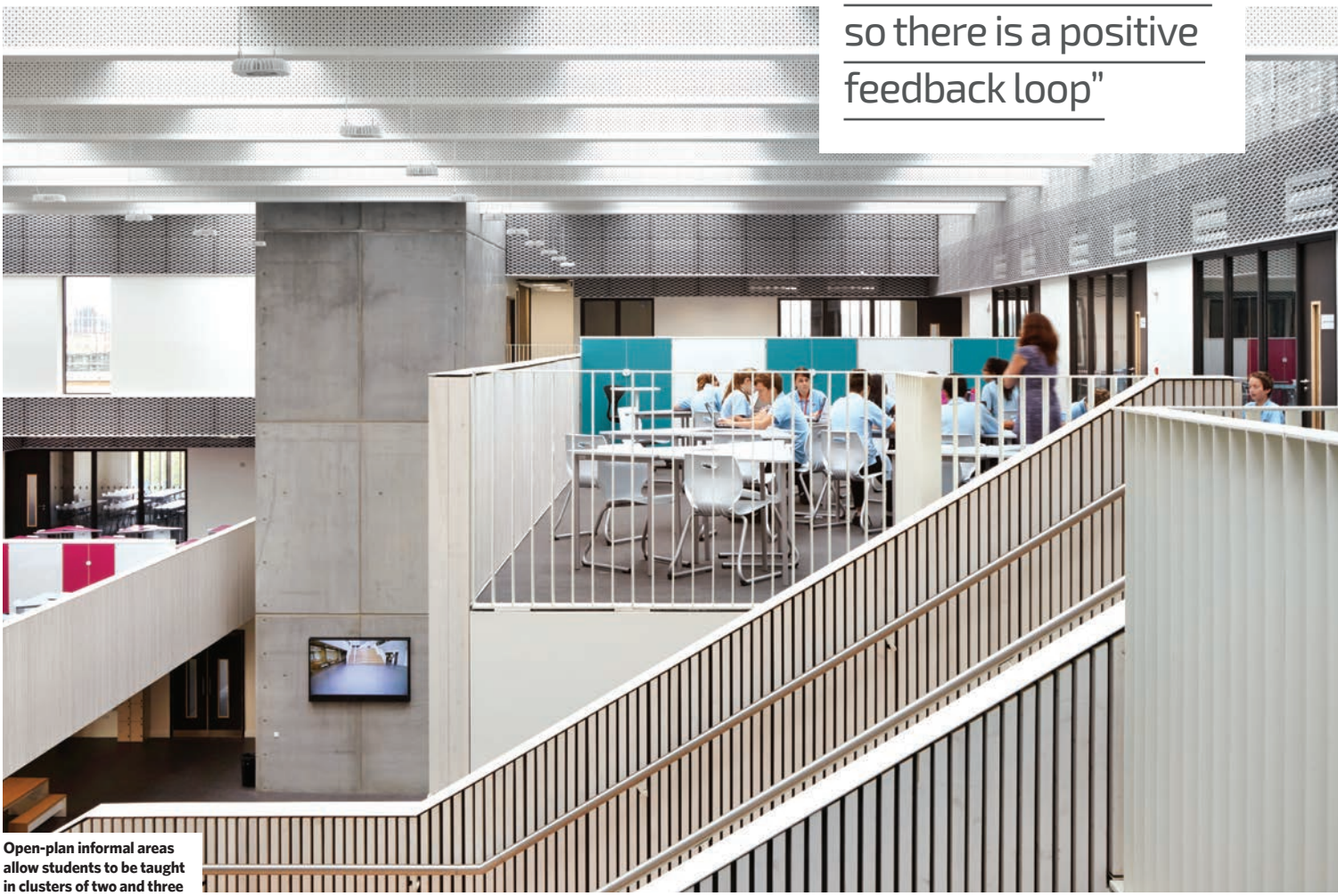
SketchUp rooflight view of first- and second-floor teaching-learning terraces and entrance foyer

» SoundSpace was also employed to show staff the effect of different occupancy levels, and their acoustic impact on pupils in the open-plan space if only 50% – or only 25% – of the recommended sound absorption was installed. 'The auralisation enabled the school to understood the importance of the acoustic treatment in enabling the effective use of the open-plan spaces,' says Novo.

In fact, the SoundSpace demonstrations were integral to convincing the client of the importance of acoustic absorption, which spared it from being reduced as part of a value-engineering exercise. Novo adds: 'The school is extremely pleased with the result, which allows them to undertake the activities that they have envisaged for the open-plan space, while creating an overall comfortable acoustic environment.' **CJ**

"Acoustic absorption results in reduced general noise, and people speaking at lower sound levels – so there is a positive feedback loop"



Open-plan informal areas allow students to be taught in clusters of two and three

Powers of concentration: biologically effective lighting's three critical 'lessons' for schools

Awareness of the positive contribution that lighting can make to students' ability to concentrate and learn is growing all the time, says Tamlite Lighting's Head of Wellbeing Debbie-Sue Farrell.

During a period when awareness of environmental factors and concern about the number of days lost to ill-health are becoming increasingly acute, it's hardly surprising that the issue of wellness in the workplace is now significantly higher than it was a decade ago. But the issue certainly isn't limited to the world of work. Researchers continue to highlight the positive contribution that better lighting can make to schools, colleges and universities.

In particular, there is now a wealth of study to reinforce the assertion that students fare better with the higher illuminance levels that are commonly found in the latest LED lighting systems. A study referenced on the Lighting for People website[1] found that children in the experimental group – which optimised lighting with a 1,000 lux illuminance level and 6,500K (cold white) colour temperature – ultimately scored significantly higher in terms of their oral reading fluency compared to a control group. The study also indicated "a positive upwards trend for motivation under the optimised lighting, while the trend for motivation under standard lighting declined during the school year."

The marked difference that good lighting can make on student productivity and effectiveness is further underlined by recent data collated by the EU-backed Lighting Europe initiative. Their research[2] notes that students can achieve up to 14% higher scores in healthy buildings equipped with optimised lighting systems. Lighting systems that complement human rhythms are crucial given that light has a demonstrable effect on three central areas, determined by Lighting Europe to be: Vision – sight, safety and orientation; Body – alertness, cognitive performance and sleep/wake cycle; and Emotion – mood, energies and relaxation. It is of course important to remember the benefit that this can have on reducing teacher/lecturer stress levels too; calmer, more engaged students will be easier to teach, after all.

Fortunately, with the latest LED lighting and control technologies, it is now easier than ever before to identify and install systems that will work to the benefit of both students and teachers.

Perfect balance

For building engineers and consultants wishing to encourage schools, colleges and universities to investigate improved lighting, the good news is that many educational establishments are increasingly looking to implement any measure that may help them in a highly competitive and rigorously tested marketplace. Focus on the following three 'lessons' and the case for upgrading may soon pass from good to compellingly persuasive...

1) Everyone accepts that temperature, humidity and ventilation are vital considerations, and the same should apply to lighting. By seeking a perfect balance between natural and artificial light, with different light output at different times of day, it is possible to offer illumination that works in conjunction with students' natural rhythms.

2) Deploying dynamic and tunable lighting systems – whereby light intensity and tuning spectrum can be adjusted in accordance with different requirements throughout the course of the day – constitutes the most effective route to achieving what is increasingly being labelled as 'biologically effective' lighting.

3) The transition to LED-based lighting has been ongoing in education for many years, but it's always worth briefly restating some of the other primary benefits. Not only does it offer a more consistent and appealing quality of light, it also uses significantly less energy and can result in RoI periods of just a year or two – even in sizeable, school-wide installations.

Engineers working with schools and colleges also need to think carefully about choosing user-friendly controllers and interfaces, allowing staff to make easy 'on the fly' adjustments in response to concerns or requests.

With a number of funding schemes – most notably Salix Finance - available to assist educational establishments to upgrade to the next-generation lighting, it would be an oversight not to mention that engaging the services of a specialist lighting company is invariably going to be an astute move. Not only will they be able to make sure the system is optimised at the time of installation, they will also be able to provide support and fine-tuning expertise as the years go by, guaranteeing that the lighting will continue to work in the favour of students and teachers.

Let us educate you on the power of lighting for wellbeing. Visit **tamlite.co.uk/wellbeing/education**

[1] http://lightingforpeople.eu/lighting-in-education/

[2] https://www.lightingeurope.org referencing www.ecodesignconsultants.co.uk/healthy-buildings/ www.cbre.nl/en/healthy-offices-research

Moving beyond energy

Evidence gathered from a school campus in London shows the lessons that can be learned from a holistic approach to building design and operation, which improves energy performance while ensuring indoor environment quality. By Dr Esfand Burman, Dr Craig Robertson and Nishesh Jain

While the primary focus of building performance evaluations that address current environmental policy requirements is on energy performance, these evaluations alone do not capture the full impact of buildings on occupants and the wider environment. The performance of a building also involves occupant wellbeing and indoor environmental quality (IEQ). Specifically for schools, there is a strong association between IEQ and cognitive performance.

The assessment of energy and IEQ performance in a recent case study of a newly built and partly refurbished school campus in London offers insights into the inter-relationship between energy and IEQ.

The building's external envelope is made of prefabricated concrete panels, while a centralised plant is designed to supply heating through a biomass boiler, with gas-fired boilers as a backup. Cooling is supplied only in the server rooms and rooms with high levels of ICT equipment. Most spaces have operable windows but, primary, fresh air is supplied by a mechanical ventilation with heat recovery system, controlled by CO_2 sensors.

Energy performance

Underperformance of buildings, post-completion, when compared with the design-stage projections is commonly referred to as the performance gap for school buildings, CarbonBuzz reports an average 54% increase in

operational CO_2 emissions compared with design estimates.

Design projections

It could be misleading to use the results of UK Building Regulations or Energy Performance Certificate (EPC) calculations carried out during design stage as the projected energy performance – and so to determine the performance gap. These calculations are meant for comparative benchmarking and assume standardised operating conditions – such as hours of operation – while excluding some energy end uses, such as small power, external lighting, lifts, and so on. So they are not truly representative of expected energy use.

Design-stage estimation of operational energy use should account for all end uses in the building, as well as realistic operating patterns and behaviour. The calculation method proposed in CIBSE TM 54 factors this in, and offers a framework for designers to undertake more realistic design calculations. In the case study building, therefore, the 64% increase in actual energy use over the baseline derived from CIBSE TM54 method is considered the performance gap because of technical and operational issues.

Energy-performance issues

Calibrated building-performance simulation models can be used to assess and validate the causes of the performance gap. Using DesignBuilder software, the calibrated model of the case study was used systematically to verify and quantify the impact of deviations of the building and its systems from design intentions. Lessons learned – based on experience – are, to a large extent, applicable to school buildings in the UK in general.

Schools have partial occupancy during half-term breaks and school holidays, and, operationally, don't simply follow the academic calendar. Even during term time, there are after-school lessons, extracurricular activities and night classes.

These transient, low-occupancy, out-of-hours uses of school buildings are often not considered in energy performance calculations at design stage – as was the case in this school project. In line with industry practices, a centralised system design and control strategy was used in this school. This led to systems being operational in multiple zones even when only a few of them were occupied.

Hydraulic isolation of heating/cooling systems and decentralised controls for areas that are not occupied can ensure large areas are not conditioned unnecessarily.

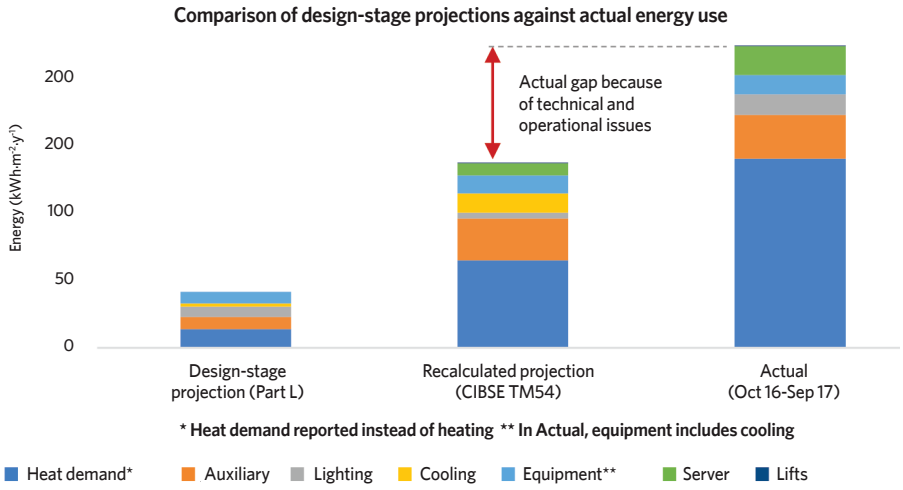


Figure 1: Results for one of the eight campus buildings

> "In sustainable, low-energy design, the ways to achieve IEQ might contradict ways to achieve better performance"

Consideration of optimum space-time utilisation strategies during building design and in operation can also be a cost-effective way of saving energy.

The biomass boiler in the school was installed to meet the CO_2 emissions criterion of Part L of the Building Regulations. This system was not operational post-handover, however, and because of the logistic limitations of running it, the school's management preferred to use the backup, gas-fired boilers.

As a result, the CO_2 emissions of the building are higher than was assumed at building completion. At policy level, robust safeguards – such as post-occupancy measurement and verification of building and system performance in its first few years – can help ensure the installed low or zero carbon strategies and technologies meet building users' expectations, and will be used in practice.

Indoor environmental quality

In the current trend for sustainable and low-energy building design, the ways to achieve high IEQ might contradict measures to achieve better energy performance. IEQ performance in the case study was generally within acceptable levels, but gave good insights into potential risks, as well as the inter-relationship of energy and IEQ performance objectives.

The case study school has appropriate heating provision and preconditioning of fresh air from the mechanical ventilation system, as well as low air permeability. This ensures energy efficiency can be achieved while maintaining a comfortable thermal environment during the heating season.

A common design strategy of exploiting thermal mass for better thermal comfort and energy efficiency was adopted by having exposed concrete ceilings in classrooms, stairwells and common spaces. Even with thermal mass, in the non-heating season – without comfort cooling – an airtight

Operationally, schools don't simply follow the academic calendar

»

» envelope with inadequate operable windows can result in summertime overheating in zones with high solar exposure. As the school had a similar environment strategy, the risk of elevated indoor temperatures was reported in the occupant surveys and it was observed in indoor temperature monitoring that some south-facing zones were at risk of elevated indoor temperatures. In the context of future climate conditions, this risk could be significantly higher.

Thermal mass use could also be coupled with night-purge ventilation to enhance its effect, which – at the time of study – was not seen to be happening in practice.

Air quality

Mechanical ventilation systems with strategies such as CO_2-based, demand-controlled ventilation (DCV) are typically used in urban schools for fresh air supply. It is an energy-efficient way to ensure an adequate amount of fresh air is delivered. In the case study building, DCV was able to maintain CO_2 concentration levels under the BB101 threshold of 1,500ppm, and a filtration system provided good protection against microparticles (PM2.5 and PM10).

Indoor CO_2–based ventilation control only may not be sufficient for dense urban environments, however, as external air can be more polluted than indoor air.

Advanced monitoring of air quality in some of the zones of the building indicated increased levels of traffic-related pollutants – benzene and nitrogen dioxide (NO_2) – during the heating season. This suggests activated carbon filters or other measures are required in the school to enact chemical filtration. These could be coupled with more advanced ventilation controls that consider the balance between the requirement for fresh air and protection from outdoor sources of pollution – to create a healthier environment and, at the same time, save energy.

Lighting and acoustics

Large windows in rooms are architecturally desirable and offer good daylight. However, along with increasing summer overheating risk, they also bring the problem of glare. It is important to achieve the right balance and to specify effective blinds in all classrooms.

This did not happen in the school during the early stages of post-occupancy, leading to complaints, but it was recognised and rectified. Additionally, the provision of operable windows for natural ventilation and free cooling in summer needs to address outdoor noise ingress. This was not a major issue in this school, but an integrated design solution should be adopted for the façade that balances all the requirements – energy, thermal comfort, lighting and acoustics.

Use of exposed concrete ceiling for thermal mass requires additional measures – such as ceiling baffles – to address the potential risks related to room acoustics

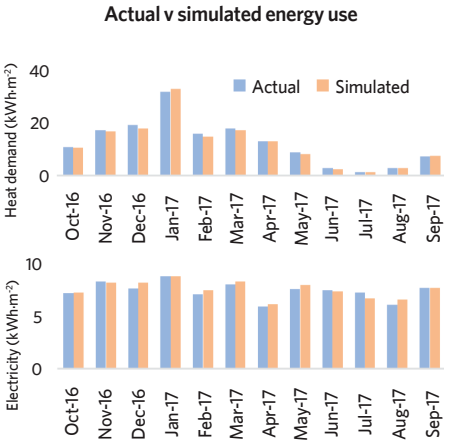


Figure 2: Energy model calibration helps to identify and validate building performance issues and assess improvement opportunities

> "Large windows are architecturally desirable and offer good daylight, but they also bring the problem of glare"

As mentioned earlier, use of exposed concrete ceilings to cater for energy efficiency and thermal-comfort requirements can conflict with space acoustics because of longer reverberation times. While the classrooms did not suffer from this issue, multipurpose space with high floor-to-ceiling heights did. Baffling in the spaces and acoustic breaks in construction assemblies can help avoid some of these issues.

Summary

It is a challenge for designers to balance energy and IEQ. A holistic energy and environmental-performance approach is necessary to address the intricate inter-relationship between these performance aspects, to avoid unintended consequences, and to address gaps in performance. This will ensure that energy efficiency is not achieved at the expense of IEQ and other aspects of building performance.

Having operational performance targets underpinned by the Soft Landings framework or a performance contract – and accounting for specific requirements for energy and IEQ – can make designers, contractors and building managers stakeholders in improving a building's operational performance. CJ

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Teaching modules

With offsite construction techniques predicted to surge in the next five years, Paul Arnold, Remeha's product manager, looks at a modular replacement boiler project for a school in Gosport

Offsite is on the rise. According to a survey by legal firm Clyde & Co, two-thirds of the top 50 construction firms anticipate doubling the amount of work they carry out offsite to improve efficiency, reduce costs, tackle the skills shortage and overcome technical challenges.

When it comes to heating, the approach can deliver huge benefits on school refurbishment projects – from greater design flexibility, to time savings for increased ease of scheduling. One example is the bespoke rig system, designed to simplify multiple boiler replacement.

School boiler replacements are usually scheduled for the summer holiday period, because upgrading a heating system is only considered feasible when the site doesn't require continuous hot water or heating for an extended period. While convenient from the school's perspective, it coincides with the busiest time of year for designers, specifiers and contractors, putting pressure on a school's maintenance team to fit the planned replacements into a tight timeframe.

In older school buildings, access limitations and a lack of available plantroom space – plus a tight, fixed installation schedule – are frequent challenges. Using site-assembled manufacturer cascade options simplifies and speeds up installation. A key benefit of the offsite rig system, however, is that all project and site requirements can be addressed and resolved from the outset, at the design stage. Indeed, this flexibility is central to its success.

The bespoke rig is based on individual boilers from 30kW to 300kW output, with no limit to the number that can be incorporated. Designers can define the maximum and minimum output, the number of boilers and whether to use a back-to-back or in-line layout. They can also address any physical site restrictions through a choice of header extensions and connections. A further option to overcome access restrictions is for the bespoke rig to be designed to split into smaller modules, with simple reconnection into a single frame in the plantroom.

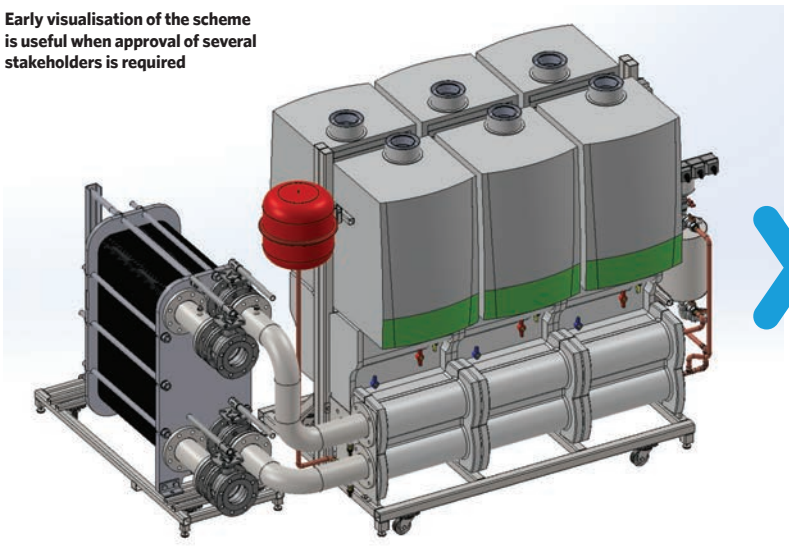
The rig can also integrate controls – such as weather compensation, sequencing or building management system (BMS) direct operation – to maximise seasonal efficiency for lower running costs.

Only once the design is clearly defined does production take place. This is carried out in a factory environment with quality-controlled, end-of-line testing giving added quality assurance. The boilers are then delivered to site on a wheeled rig unit. The position and size of the system connections on the rig can be produced to match the system pipework in the plantroom, which means it is ready for rapid, easy connection to the system.

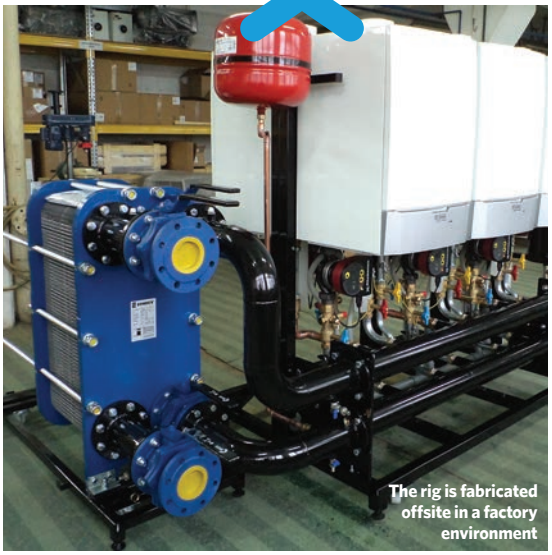
Replacing larger boiler units with multiple, fully modulating condensing ones also achieves a greater turndown ratio, allowing the boilers to adapt to fluctuating heat demand for more efficient energy use and increased reliability. It also makes for easier future maintenance and uninterrupted heating provision.

Bridgemary School in Gosport, run by the Kemnal Academies Trust, has recently replaced two pressure-jet boilers with

The boilers are delivered to site on a wheeled rig unit



Early visualisation of the scheme is useful when approval of several stakeholders is required



The rig is fabricated offsite in a factory environment

modular ones. Consultant engineer Fred Edwards, at Ridge and Partners, specified six boilers on a wheeled rig unit to achieve the improved reliability and high efficiency required by the trust.

In addition to the plantroom space restrictions and tight schedule, the primary and secondary circuits needed to be segregated to optimise boiler performance and longevity. Installing the boilers on a bespoke rig met all these requirements.

Working with Ridge, Remeha prepared detailed 3D drawings of the layout. Such early visualisation is particularly useful for schools, for which boiler replacements must be approved by a number of stakeholders. The drawings formed part of a comprehensive operations and maintenance documentation manual for Bridgemary School, for simpler future servicing.

Plate heat exchangers (PHEs) are increasingly applied to achieve hydraulic separation between the boiler circuit and the heating circuit. At Bridgemary School, the PHE was selected to meet the specified boiler output and temperature, and orientated on the rig to meet the consultant's requirements for non-disruptive future servicing. Air-dirt separation was installed to protect the PHE from the older, retained, secondary pipework.

Integrated into the design are pumps specifically selected for the duty required for PHE operation, an expansion vessel, a pressurisation unit, and a dosing pot to ensure good-condition water.

To shave more time off installation, the controls were pre-wired for faster connection to the new BMS control panel. 'The bespoke rig was great,' said project contractor IDWe's Paul Neve. 'It was wheeled straight off the tail-lift and into place, saving us a lot of valuable time.'

With installation and commissioning reduced to days rather than weeks, there is greater planning flexibility; boiler replacements need no longer be restricted to the long summer holidays. For consultant engineers, greater design flexibility makes it easier to meet all project and customer requirements – and there is full assurance the specification has been met.

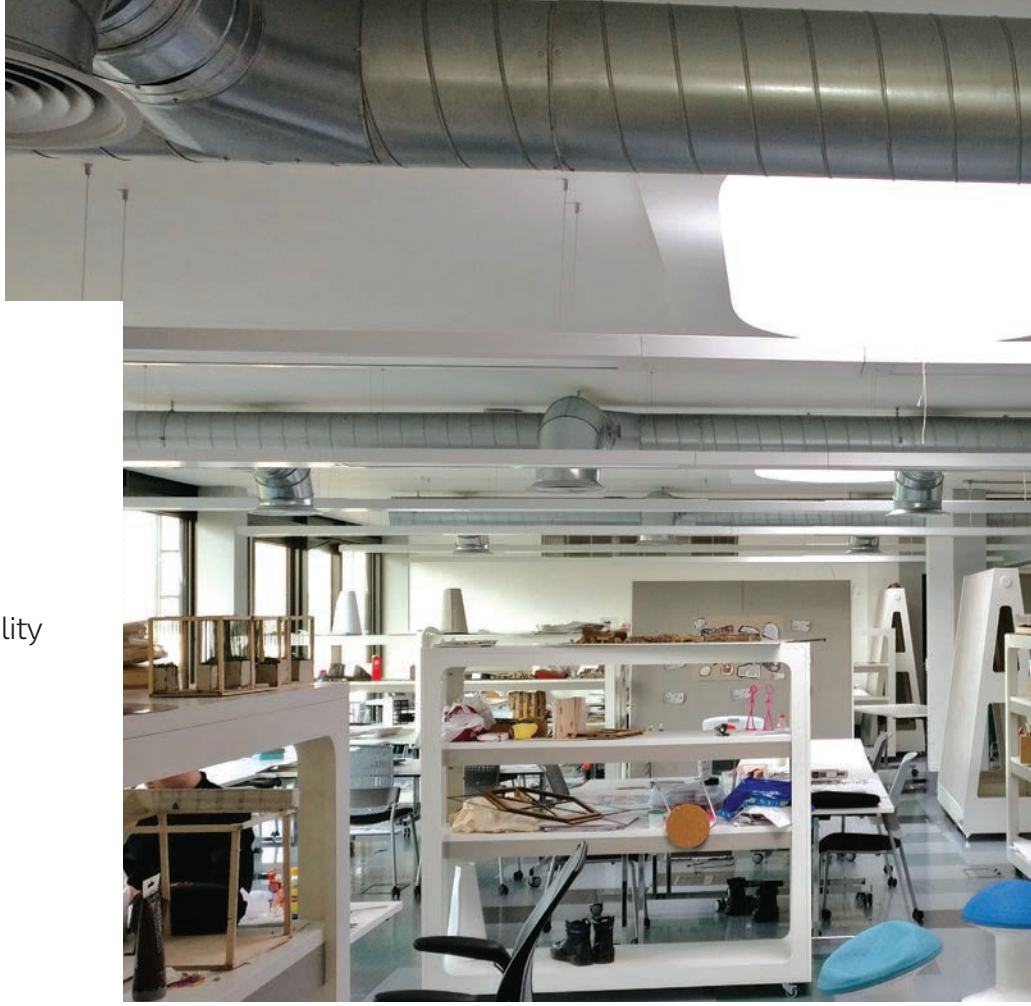
> "With installation and commissioning reduced to days rather than weeks, there is greater planning flexibility"

As the bespoke rig system lessens the intensity of skills required onsite, it is easier for contractors to plan ahead and put these skills to use on other projects. Hot works are also reduced, creating a safer environment for installers and the client.

For schools striving to improve their energy efficiency, an offsite heating solution, such as the bespoke rig, delivers at every stage of the project – from design and specification, to installation, commissioning and future maintenance. **CJ**

Study time

Indoor environment and air quality standards should focus more on volatile organic compounds to help protect young people in educational buildings



Air pollution is a key determinant of health, and there is conclusive evidence of the correlation between air quality and the incidence and severity of cardiovascular disease and lung health, among other conditions.

Indoor air quality (IAQ) within educational buildings is a growing public health concern because children and adolescents are particularly susceptible to poor air quality. According to the Royal College of Paediatrics and Child Health (RCPCH), children breathe higher volumes of air relative to their body weights, because their tissues and organs are still developing (RCPCH, 2016).

As well as precipitating short- and long-term health problems, indoor air pollution affects student productivity, degrading the learning environment and reducing academic attainment (Kim, J et al, 2006; Shaughnessy, R J et al, 2006).

Various IAQ guidelines have been developed to help mitigate the problem. These typically stipulate binding criteria in relation to CO_2 concentrations (see Table 2), which need to be maintained by a ventilation system to supply acceptable IAQ.

However, use of CO_2 concentration as a metric for good IAQ largely ignores the risks posed by diverse indoor pollutants, which are of particular importance in a school environment. Students spend about 30% of their lives in schools, and about 70% of their time during school days inside a classroom. Despite this, relatively little has been published on indoor air contaminants arising from within educational buildings, with a paucity of research about the impact of refurbishment measures on IAQ.

Monitoring campaign

One of the main contributors to indoor air pollution is the emission of volatile organic compounds (VOCs) from building materials and consumer products.

To assess the IAQ implications of ventilation in accordance with the existing standards (Table 2), a broad IAQ-monitoring campaign was implemented in a study that considered a recently refurbished educational building at Loughborough University (image above).

The study measured CO_2 concentrations continuously over a four-month period, while discrete diffusive (passive) air sampling regimes were conducted to identify all VOCs in the space. This allowed for the detection of VOCs from various sources, rather than limiting the findings to specific, known compounds.

The influence of outdoor air brought in via the ventilation system was not studied directly, as this would have required repeated, long-term sampling in the vicinity of the buildings to establish the repeatability of the compounds identified (typically spanning two seasons, to capture the cold and warm periods of the year).

Thus, a working methodology was devised to understand, within a relatively short timeframe, the likely extent of exposure to VOCs for the building's occupants and whether this could engender any serious health risks.

The CO_2 concentrations measured from May to August 2018 were found to be well within the ventilation standards/guidance limits suggested by BB101 (2018) and the Well Building Standard (2018).

Diffusive sampling was conducted for the same monitored environment with the help of a blank and exposed passive sampling tube. After collection of each indoor air sample, it was analysed by thermal desorption gas chromatography and mass spectrometry. This analysis produced a series of graphs known as chromatograms, which represent the number of identified and unidentified compounds in the air sample.

"Identification and quantification of all VOCs in indoor air is difficult because the knowledge base is still sparse"

Monitored environment, architecture studio, Keith Green Building, Loughborough University

Compound	Possible sources in the indoor environment	Health risks
Acetic acid	Computer monitors, air fresheners.	Acetic acid can cause irritation to eyes, nose and throat. Long-term exposure can lead to blackening of skin.
Toluene	■ Used in the manufacture of polyurethane foam insulation ■ Printers ■ Photocopiers ■ Faxes ■ Air fresheners ■ All-purpose cleaners ■ Detergents ■ Monitors ■ Personal computers ■ Car exhausts ■ Floor-mopping products ■ Paint ■ Lacquer ■ Dyes ■ Books	Toluene is a reasonably anticipated human carcinogen. It can cause irritation to eyes and nose. Low-to-moderate levels can cause tiredness, confusion, weakness and nausea. Long-term daily exposure can cause hearing and colour vision loss.
Benzaldehyde	■ Floor polish ■ All-purpose cleaners ■ Printers ■ Photocopiers ■ Faxes ■ Personal computers ■ Monitors ■ TV sets ■ Air fresheners	Breathing benzaldehyde can irritate the nose and throat, causing coughing and shortness of breath. Contact can irritate the skin and eyes, and repeated exposure can cause a skin rash to develop. Mild exposure can cause dizziness and skin allergies. Higher levels can cause seizures and blackouts. Benzaldehyde can cause mutations and should be handled with extreme caution.
Phenol	■ Floor polish ■ Personal computers ■ TV sets ■ Consumer products ■ Second-hand smoke ■ Cork tiles	Phenol can cause irritation to eyes, nose and throat. Short-term exposures can cause respiratory irritation, headaches and burning eyes. Skin exposure can lead to skin burns and irregular heartbeat.

Table 1: Possible sources and health risks of the compounds repeatedly found in the indoor environment

It can be seen that there are numerous VOCs in the monitored environment, as evidenced by the peaks, indicating the presence of significant atmospheric chemistry. A summary of the compounds seen repeatedly are shown in Table 1.

Volatile organic compounds

VOCs are carbon-based chemicals, and their concentration is higher indoors than outdoors because of numerous indoor sources, limited dilution volumes and relatively low ventilation rates.

Individual VOC concentrations depend on the presence or absence of an extremely wide range of potential emission sources. Identification and quantification of all VOCs in indoor air is difficult because the knowledge base is still sparse, so guidelines and researchers tend to adopt the simplified method of assessing total volatile organic compounds (TVOCs) rather than individual values. The summation of concentrations of the identified and non-identified VOCs in the measured air sample gives the TVOC value.

This approach is of little help in determining the toxicological properties of specific substances, or the precise source or extent of a problem.

Because of the paucity of guidance on the estimation of individual VOCs and their contribution to IAQ, TVOC concentrations above 300g·m^{-3} (averaged over an eight-hour period) have been widely adopted as an indicator of poor IAQ by the UK Building Regulations (2010), Approved Document F, BB101 (2018) and Breeam (2018). Despite the reference to TVOCs in such documents, there is an inadequate scientific basis from which to establish limiting values/guidelines for TVOCs, and considering it in this way presents an unquantifiable risk for health and wellbeing effects occurring within buildings.

More research needs to be done to understand the combined effect of two (or more) pollutants that can be synergistic (C>A+B), additive (C=A+B), antagonistic (C<A+B) or independent. This points towards the need for more stringent building regulations relating to IAQ monitoring, to prevent health impacts from poor air quality.

Some preventative solutions could include:

- Filters capable of trapping a wide range of pollutants, combined with an active maintenance plan
- Biophilic design to absorb some of the pollutants generated indoors

»

» ■ Low VOC-emitting building materials and consumer products
■ Development of a robust monitoring technology that can detect a wide range of VOCs, help monitor risks and identify suitable mitigation measures.

In general, ways of preventing VOCs being introduced into the internal environment are preferable to filtration and dilution. However, this implies a far higher degree of awareness and labelling of construction material specifications and the consumer products routinely used in educational buildings.

Moreover, building facility managers/employers should be required to monitor the air quality within an occupied space and report it in a standardised format, to inform occupants of the risks associated with breathing the building's indoor air. This should form an essential part of progressive environmental assessment methods, such as Breeam and the Well Building Standard.

There needs to be a shift away from correlating good indoor air quality with CO_2 concentrations and, instead, a total concentration of VOCs is required.

Specifying low VOC-emitting materials can help mitigate poor IAQ to an extent. However, VOCs can be formed through interaction with other VOCs or because of photolysis, hydrolysis or oxidation taking place in the indoor environment, so further studies documenting the hazardous properties of VOCs and the dynamic nature of their emissions are needed to help eliminate VOC risks. CJ

■ **REFERENCES:** Please visit this article at **www.cibsejournal.com** for a full list of references.

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■ **AUTHOR CREDITS: Melvin Mathew, Dr Rob McLeod, Dr Dahlia Salman** and **Professor Paul Thomas**

	Ventilation standard/ guidance	Carbon dioxide (CO_2) limits
1	Education and Skills Funding Agency (ESFA), Annex 2F, 2017	'Daily average concentration of carbon dioxide during the occupied period of less than 1,000ppm and so that the maximum concentration does not exceed 1,500ppm for more than 20 consecutive minutes each day, when the number of room occupants is equal to, or less than, the design occupancy'
2	Guidelines on ventilation, thermal comfort and indoor air quality in schools (BB101, 2018)	Similar to ESFA
3	CIBSE Guide B2 (2016)	800-1,000ppm recommended range
4	International Well Building Institute (IWBI), Well Building Standard	Below 800ppm

Table 2: Ventilation standards and the criteria for good IAQ applicable in the UK

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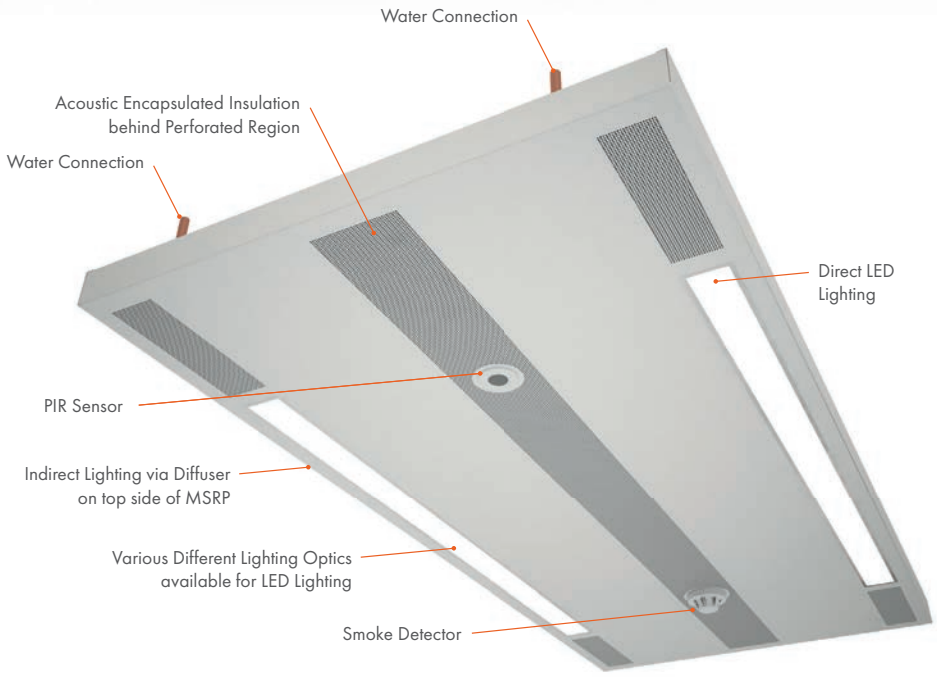

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