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EFA PSBP

Natural Ventilation Strategy

Introduction

The Baseline Designs Project will provide scheme design details for a number of Primary and Secondary School Exemplars. For the purposes of setting a reference location for the schools, Birmingham has been selected.

It is recognised that there are a number of existing schools which are failing to deliver adequate conditions for teaching in terms of air quality and thermal comfort. Furthermore, the energy efficiency of naturally ventilated buildings has been questioned due to the inability to recover heat while providing outside air in winter.

In developing the baseline designs, possible causes of why schools are failing to perform have been considered and practical solutions developed to overcome these.

The current methodology for defining comfort in teaching spaces defined in BB101 has been reviewed and an alternative methodology, proposed by the CIBSE Overheating Task Force, has been adopted. This provides a more rigorous means of assessing occupant thermal comfort as it considers operative temperature which is a better measure of comfort than the currently used air temperature. The new requirements are detailed in the PSBP Output Specification. The Education Funding Agency plans to update BB101 in 2015 to include the Adaptive Comfort criteria used in the baseline designs and included in the Facilities Output Specification for the Priority Schools Building Programme.

This report explains these changes and shows how the principles have been applied to the baseline designs.

1.1 Relevant legislation

1.1.1 The Building Regulations 2010

Part L 2A Criterion 3 of Approved Document 2A sets out the approach to limiting heat gains in buildings as required by paragraph L1(a)(i) of schedule 1 to the Building Regulations. The intention is to limit solar gains during the summer period to either reduce the need for air conditioning or reduce the installed capacity of any air conditioning system installed.

However the guidance to Part L recognised that for naturally ventilated buildings, limiting solar gain is not sufficient to provide a satisfactory level of comfort and quotes Building Bulleting 101

Design of Ventilation in Schools as a source of guidance for assessing overheating risk in educational buildings.

In relation to ventilation requirements of schools, Part F Table 6.3 also references BB101 as a guide which when followed will satisfy the legislative requirements for ventilation of schools.

1.2 Design standards

1.2.1 Thermal comfort

The adaptive comfort approach follows the methodology and recommendations of European Standard EN 15251 to determine whether a building is likely to overheat, or in the case of an existing building whether it can be classed as overheating.

A limitation of the current comfort criteria outlined in BB101 is that they are referencing Air Temperature only which is a poor means of defining comfort. The Adaptive Comfort Approach (ACA) used in the baseline designs is based on Operative Temperature and more closely tracks the heat exchange that occurs between occupants and their surroundings by accounting for Radiant Temperatures.

Furthermore the outside reference level is fixed in BB101 which takes no account of the variability of weather and the adaptability of people in response to changing temperatures. The new criteria are based on a variable (adaptive) temperature threshold that is generated from the outside running-mean dry-bulb temperature.

The new methodology assesses the risk of overheating using three criteria:

Criteria 1 - Hours of Exceedence (H_e): The number of hours the predicted operative temperature exceeds the maximum acceptable operative temperature (θ_{max}) by 1K, or more, must not exceed 3% of the total occupied hours or 40 hours, whichever is the smaller, during the five summer months (May-September) .

Criteria 2 - Weighted Exceedance (W_e): The sum of the weighted exceedance for each degree K above θ_{max} (1K, 2K and 3K) is ≤ 10.0; where We = ΣH_e(1,2,3)*(Δ T)2(1,2,3) and Δ T = ($\theta_{op} - \theta_{max}$), rounded to a whole number i.e. [$0^oC < 0.5°C \geq 1°C$].

This criterion covers the severity of overheating, which is arguably more important than its frequency, and sets a daily limit of acceptability.

The criteria is based on Method B – 'Degree hours criteria' in BS EN15251; 2007 and is the time (hours and part hours) during which the operative temperature exceeds the daily T_{max} during the occupied hours, weighted by a factor which is a function depending on by how many degrees the range has been exceeded. The Overheating Task Force has interpreted this weighting factor as being 1 for Δ T = 1K, 2 for Δ T = 2K and 3K for Δ T = 3K,

The value of 10.0 is an initial assessment of what constitutes an acceptable limit of overheating for the building type and is derived from 2hr @ a Δ T of 1K + 1hr @ a Δ T of 2K + 0.5hrs @ a Δ T of 3K i.e. {<(2*[1]2 + (1*[2] 2 + (0.5*[3] 2)}

Criteria 3 - Threshold/Upper Limit Temperature (θ_{upp}): The measured/predicted operative temperature should not exceed the θ_{max} by 4K or more at any time.

The building will be 'deemed' to have overheated if any two of the three criteria are exceeded.

1.2.2 Air Quality

BB101 recommends that ventilation should be provided to limit the concentration of carbon dioxide in all teaching and learning spaces. When measured at seated head height, during the continuous period between the start and finish of teaching on any day, the average concentration of carbon dioxide should not exceed 1500 parts per million (ppm).

This criterion is superseded for the PSBP by the following criteria:

Ventilation should be provided to limit the concentration of carbon dioxide measured at seated head height in all teaching and learning spaces.
Where mechanical ventilation is used or when hybrid systems are operating in mechanical mode, ie the driving force is provided by a fan, sufficient fresh air should be provided to achieve a daily average concentration of carbon dioxide during the occupied period of less than 1000ppm and so that the maximum concentration does not exceed 1,500ppm for more than 20 consecutive minutes each day.

Where natural ventilation is used or when hybrid or mixed mode systems are operating in natural mode, ie the driving force is either buoyancy or wind, sufficient fresh air should be provided to achieve a daily average concentration of carbon dioxide during the occupied period of less than 1500ppm and so that the maximum concentration does not exceed 2,000ppm for more than 20 consecutive minutes each day.

These performance standards are based on the need to control carbon dioxide resulting from the respiration of occupants. In general teaching and learning spaces, in the absence of any other major pollutants, carbon dioxide is taken to be the key indicator of ventilation performance for the control of indoor air quality.

The performance standards will not, however, be sufficient for areas used for special activities, such as science laboratories and food technology rooms etc when higher air change rates are needed.

Outside carbon dioxide concentrations are generally around 380ppm. For a typical classroom with 30 students and 2 staff, a fresh air ventilation rate of between 8 and 9 l/s/person corresponds to a carbon dioxide level of around 1000ppm under steady state conditions depending on the ventilation system. A fresh air rate of 5l/s/person corresponds to around 1500ppm.

The design of ventilation openings to deliver these carbon dioxide (CO_2) levels should be based on the maximum number of occupants the space is designed to accommodate.

1.3 Principles

The baseline schools were designed to deliver the principles of the PSBP Facility Output Specification requirements and not simply comply with the design criteria. The main principles in relation to the school designs are discussed below.

1.3.1 Weather files

The weather files against which the baseline designs have been tested are the Design Summer Year (DSY). This is a change from the Test Reference Year (TRY) required in BB101 and represents a significantly warmer weather condition.

1.3.2 Natural Ventilation

The adaptive temperature criteria are a more demanding method of measuring comfort than BB101. As a result the schools have been designed to allow large volumes of air to move through the teaching spaces through the use of atria, cross ventilation and stacks. This provides a means of venting the internal heat gains while providing outside air to the occupants.

High and low level openings provide sufficient ventilation area and a means of reducing draughts in the occupied zone by directing the air flow above the occupied zone under windy conditions. The high level openings are also better able to cool the thermal mass of the soffit.

Internal blinds and/or other shading devices are essential for glare control and with openable windows there is a conflict as the blinds frequently block the air path. The baseline design ventilation is either via opaque ventilation louvres or openable windows which have blinds tracked in the frame or a combination of both.

1.3.3 Solar Control

Climate based daylight modelling has been used to design the levels of daylight in the baseline designs. This has resulted in a reduced area of glass on the facades when compared to the daylight factor methodology for determining daylight performance. This has significantly reduced the solar gain to the classrooms and the associated risk of overheating. Additionally, the analysis has been based on high performance glazing on the most exposed east, south and west facades with a maximum g-value of 0.32. These east, south and west facades also have a light shelf, which reflects daylight to the back of the classrooms and provides some shade to the lower window elements.

1.3.4 Restrictors

Windows are frequently restricted to 100mm in schools in order to prevent people accidentally falling out. When incorporated late in the design process they are poorly integrated and can block the air flow into the rooms. This can result in overheating and irritation if the blind knocks against the window frame.

There is no requirement in health and safety legislation to fit window restrictors on all buildings. However, schools do need to consider the risk of falling from windows as part of their wider assessment of risks - in some schools this may be more than accidental risk and may include falls related to a pupil’s vulnerability (e.g. some pupils with complex special needs) or deliberate harm.

Where higher risks of falling from opening windows are identified, the risks can be reduced by restricting the window in some way. Guidance on the amount of restriction to prevent the risk from falls in a range of situations is given in: BS 8213 – 1: 2004 Windows, doors and roof lights – Part 1: Paragraph 5.4.1. BS 8213 recommends fitting safety restrictors to accessible opening lights where children or adults are at risk of falling out. Paragraph 3.14 defines a safety restrictor as a mechanical device, which is intended to limit the initial movement of an opening light so that a clear opening of not more than 100mm is achieved at any point.

1.3.5 Thermal Mass Night Purge

The incorporation of operative temperature within the adaptive criteria approach highlights the benefit of thermal mass in terms of the reduced risk of overheating. All the baseline classrooms have been designed with exposed concrete soffits to provide lower operative temperatures. The thermal mass is in the soffit as all the occupants will be exposed to the overhead radiant cooling effect as opposed to walls which can have coverings which can obscure the mass from the occupants. Similarly lattice ceilings, rafts and metal decking can reduce the effectiveness of the thermal mass and were avoided. The acoustic requirements of the classroom required absorbent materials to be applied and 40% of the soffit is obscured by acoustic panels.

Thermal mass alone will not provide significant benefit unless a night purge ventilation strategy is applied using night air to cool the soffit. This will be achieved through high level openings.

1.3.6 Controls

The control strategy for the schools has been kept as simple as possible. This means that there is less to go wrong and the mode of operation is more readily understood by the occupants and maintenance staff.

The high level openings are controlled by actuators which are linked to CO_2 and temperature sensors. This provides a minimum level of outside air and temperature regulation, and additional ventilation is provided by manual openable windows. When the outside temperature is low the windows will no longer open automatically and mechanical or hybrid ventilation systems must be used to control the CO_2 levels.

1.3.7 Energy Efficiency

To minimise ventilation losses during the heating season, the baseline designs are provided with mechanical ventilation with heat recovery. This is by means of either standalone room units ducted to the façades or centrally-based units ducted to each of the classrooms. In each case, high efficiency DC motor fans with minimal external resistance are used to limit fan power. Variable volume fans allow individual classrooms to regulate CO_2 levels in line with the occupancy using sensors.

Heat emitters are located against an internal wall and not along the perimeter as high levels of insulation in the facades prevent draughts. Locating the emitter from the perimeter encourages the occupants to manage the openings as opposed to leaving window opens and relying on the radiators to heat up the incoming air.

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The heating radiator flow valve is controlled by a temperature sensor in the occupied zone which is not located at the air handling unit supply. This is to prevent the sensor reading the air temperature before it has mixed with the room air which would not be representative of the average condition.

1.4 Finger Block School Design

1.4.1 Natural Ventilation strategy

All teaching rooms are designed for stack or cross ventilation and are at least 3.3m high and 7.8m deep, with the exception of a few 9m deep rooms,

The windows are fixed and ventilation is provided by a separate set of insulated ventilated louvres adjacent to the windows. The window blind can therefore be deployed without obstructing the airflow.

The exposed concrete soffits will require night purge ventilation which is provided through the louvres at high level. This reduces the security risk and the need for restrictors is removed.

At the back of the ground and first floor classrooms are attenuated opening slots which connect the rooms with the circulation space behind.

The corridor has a series of long, 1m wide slots along the corridor which link the corridor vertically through the building. These slots provide some daylight through the circulation area and an exhaust air path for the classrooms.

There is an upstand over the circulation roof which has banks of insulated louvres either side. These louvres are under actuator control which will close the set on the windward side to encourage air to exhaust.

The fire strategy requires the top floor circulation corridor to be separated from the classrooms and the rooms are ventilated directly to outside through roof terminals. These terminals will have a glazed window under actuator control which will also allow daylight into the back of the rooms.

Section through classroom block showing summertime ventilation strategy

Section through dining hall showing summertime ventilation strategy

The sports hall has high level actuated windows to allow cross ventilation without excessive air movement within the occupied zone.

The dining room provides an exhaust air path for the adjacent teaching spaces. There is an upstand which has banks of insulated louvres either side. These louvres are under actuator control and will close the set on the windward side to encourage air to exhaust. Openable windows in the façade at level three will provide additional ventilation to the atrium.

1.4.2 Mechanical Ventilation

A room ventilation unit will provide fresh air to the teaching rooms primarily when the outside temperature drops to the point when the internal loads are insufficient to heat the incoming air to a comfortable condition.

It is located at high level on the end wall in a bulkhead; access is provided for maintenance and cleaning.

A radiator located on the end wall provides space heating and out of hours frost protection.

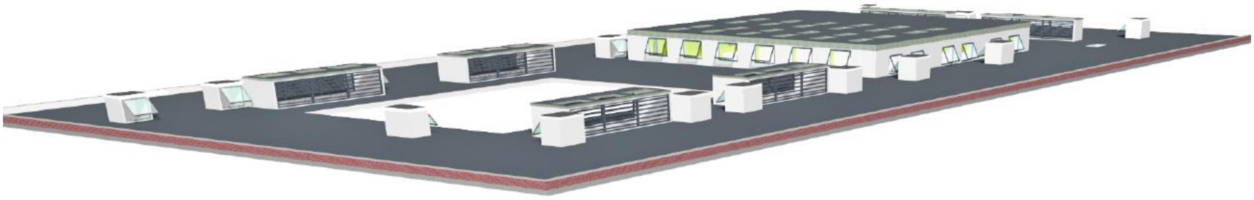
The hall has a dedicated mechanical ventilation system mounted at roof level. This incorporates high efficiency fans and heat recovery. CO2 sensing and absence detection control the volume according to occupancy.

1.5 Super Block School Design

1.5.1 Natural Ventilation strategy

The classroom ventilation strategy follows the same principles previously outlined combining cross ventilation with exposed soffits and night purge ventilation. This also includes the return air path for the ground and first floor rooms, via attenuated openings, through the circulation spaces and exhausting at roof level.

The top floor rooms have dedicated roof openings which allow daylight to the back of the rooms.



The atrium over the dining hall acts as a return air path for a number of adjacent classrooms except for the top floors which have dedicated stacks. Vertical windows in the upstand on either side of the atrium provide cross ventilation to the dining hall. If required additional air can be provided at low level through the entrance doors.

1.5.2 Mechanical Ventilation

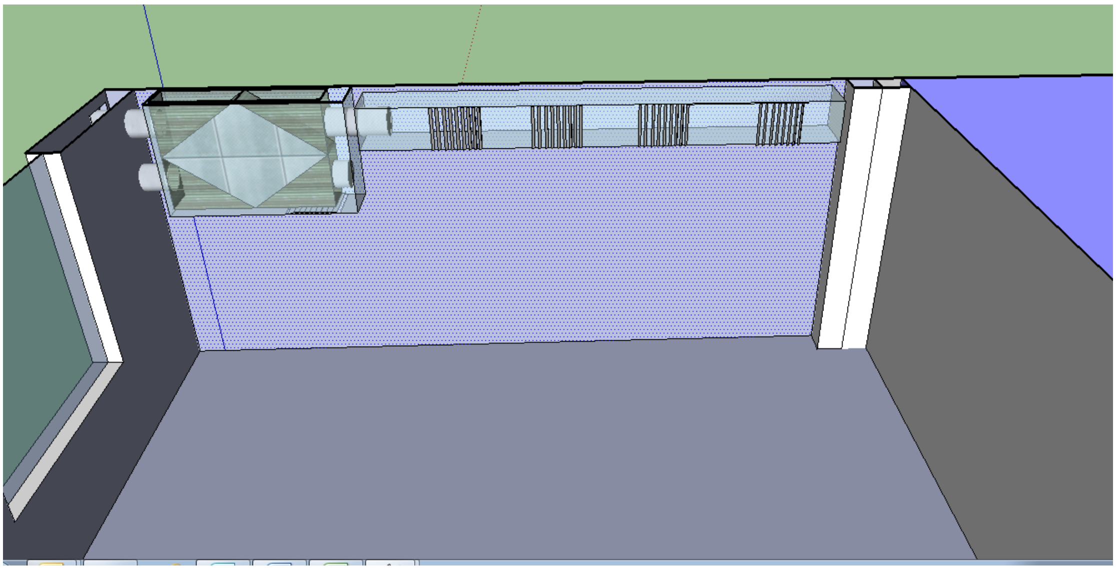
A room ventilation unit provides fresh air to the teaching rooms primarily when the outside temperature drops to the point when the internal loads are insufficient to heat the outside air to a comfortable condition.

It is located at high level on the end wall in a bulkhead accessible for maintenance and cleaning.

A radiator located on the end wall provides space heating and out of hours frost protection.

The hall has dedicated mechanical ventilation mounted at roof level. This incorporates high efficiency fans and heat recovery. CO2 sensing and absence detection control the volume according to occupancy.

Drawing showing mechanical ventilation heat recovery unit for a classroom for wintertime ventilation



1.6 Primary School Design

1.6.1 Natural Ventilation strategy

The teaching rooms in the primary are designed for stack or cross ventilation and measure 3.0m high by 7.2m deep. The windows are openable with a blind to the top windows and a separate blind on the bottom to limit the obstruction to air flow.

On the ground floor each single aspect teaching space connects to two ventilation stacks which rise up through the building to vent through the roof of the circulation area. The two end classrooms do not have stacks, one has an air path over the nursery group room to allow cross ventilation to outside and the other has a window located in the end wall venting straight to outside.

The first floor single aspect rooms have stacks at the back which rise directly through the roof. The end rooms have windows in the flanking wall which provides a cross ventilation path.

The exposed concrete soffits will require night purge ventilation. This is achieved through the stacks which are controlled by actuators.

1.6.2 Mechanical Ventilation

An insulated roof mounted ventilation unit provides fresh air to the teaching spaces. It incorporates high efficiency fans and heat recovery to reduce energy consumption. The air handling unit is ducted to the natural ventilation stacks, one acts as a supply and the other a return. The large cross sectional area of the stacks reduces the air resistance and as a result the required fan power. Insulated dampers at the top of the stack close when in mechanical ventilation mode to prevent short circuiting of the air.

Radiators within the teaching space provide space heating and out of hours frost protection.