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Fresh Air. Fresh People.

How to avoid draught using natural ventilation

There are, unfortunately, too many examples of poorly implemented natural ventilation strategies where the design may have been compromised or de-engineered to meet a budget, or even poorly designed from the outset. These examples have obviously made designers, contractors and clients aware of the negative aspects that can arise from any poor ventilation strategy

In this paper, WindowMaster would like to demonstrate some simple, but essential, design criteria which must be implemented, regardless of budget, in order to ensure that a low energy, natural ventilation system can deliver the required indoor air quality and comfort levels.

WindowMaster has been promoting a better understanding of how to avoid troublesome draughts for many years and, if understood and properly controlled, the problems can be mitigated.

Simple "rules of thumb" are not enough

Indoor climate experts can predict the detailed air movement within a room using simulation tools, Computational Fluid Dynamics (CFD) is one of the most commonly used. Therefore, the problems associated with poor design, such as draughts, can be eliminated, without the need for fans, mixing boxes or other mechanical equipment. Simple calculation tools and "rules of thumb" may not be accurate enough to predict the real impacts of the coanda effect and the heat plumes from internal heat sources, such as the occupants.

WindowMaster has therefore carried out detailed CFD modelling to analyse the natural mixing of cold external air in a classroom during winter. One of the key points to note in this modelling is that there are no radiators or other heat sources operating when the windows are opened. This is due to the fact that the internal heat gains are quite high in a classroom and these can easily pre-heat the incoming air.

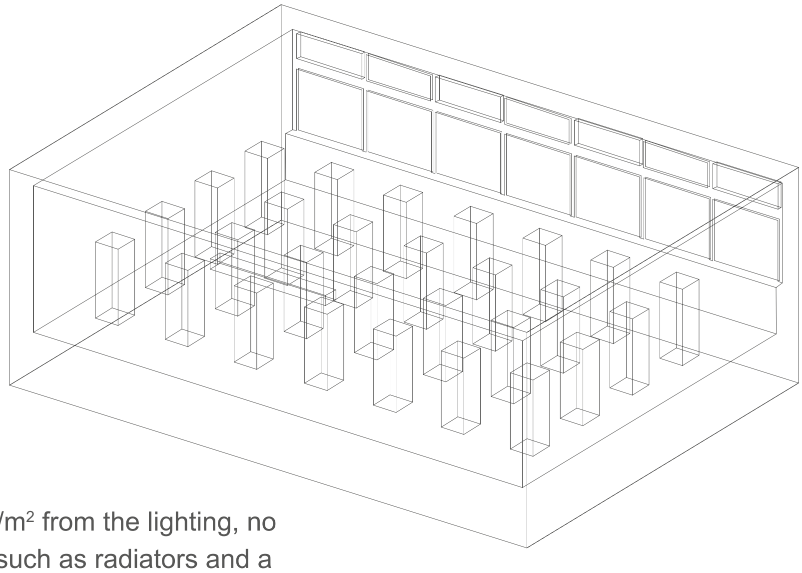
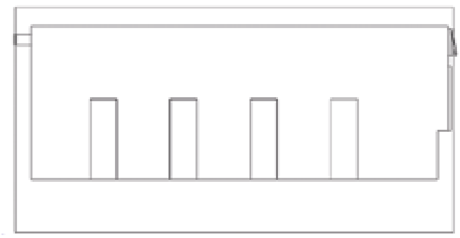


Figure 1 3D model of classroom, with a section shown below



Internal CFD calculation

In the model, WindowMaster have used four automated high level, top hung, outward opening windows to demonstrate the mixing of the air at high level and to show the lack of draught around the occupants.

The external temperature is 5°C which means that when the windows are opened 5°C cold air enters the space. The flow of cooler outside air into the space is very closely controlled and is therefore heated by the warm internal air and some of the building surfaces before reaching the occupants. The flow rate is modeled as close as possible to 5 l/s per person (it is actually at 156 l/s in total), which is required to keep the IAQ (CO_2) below 1500ppm.
The approach is very conservative, as the model assumes only 28 pupils, no heat gain from computers, only 8W/m² from the lighting, no heating such as radiators and a large classroom, which gives a lower W/m² than would be expected in the real scenario.

As stated previously, in the classroom there are four high level automated windows and in the rear of the classroom is a high level, sound attenuated vent to exhaust the air into the atrium.

Results

The following results are from when there are no changes and a steady state condition is achieved.

The figures illustrate the temperature and the air velocity distribution when the windows are opened and 5°C cold air enters the classroom at the required rate to provide the 5 l/s per person.

Internal loads		Unit
Occupancy	28	People
Heat gain from people	75	W/person
Lighting	8	W/m²
Geometry		
Floor area	80	m²
Floor to ceiling height	3	m
Wind speed	1.1	m/s

Table 1 Assumptions for the CFD calculation

Temperature distribution

One of the key elements in natural ventilation is to have very precise control of the windows. The challenge during wintertime is not to get enough air into the building – it is to limit the air entering the room. Opening the windows during the wintertime can, with the right fine control, provide satisfactory wintertime ventilation performance without draughts in the occupied zone. This is illustrated in the following figures.

The temperature distribution shows that the cold, incoming air (5°C) mixes with the warm internal air at high level before reaching the occupants (the white boxes). The air being delivered to the occupants is around 19-20°C (in yellow).

Figure 2 is a perfect example illustrating the coanda effect where the incoming air attaches to the ceiling, which results in the cooler air reaching even further into the space, making it possible to avoid draught. The attachment of the jet (air) to the surface only occurs when the distance between the supply inlet and the ceiling surface is below a certain value, otherwise the jet will propagate as a free jet. The section across the classroom in Figure 2 is one of the most informative images, as it illustrates exactly the air flow via an open window and how this develops.

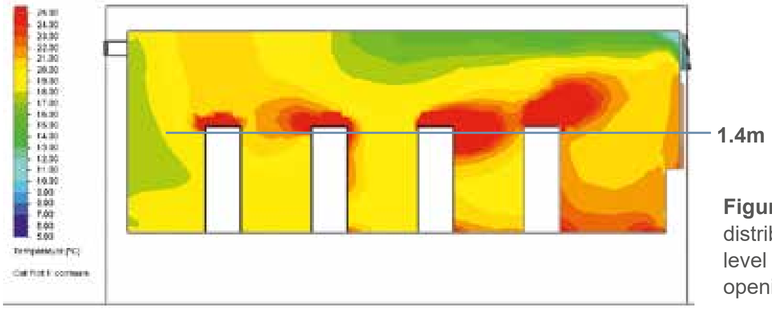


Figure 2 Temperature distribution for high level tophung outward opening windows

The thermal comfort requirement is achieved:
Cold incoming air mixes with warm internal air at high level.

Cross sections around the pupils have also been modelled, in order to investigate if any localized issues arise. In Figure 3, the temperature distribution around the occupants can clearly be seen. The temperature in the occupied zone remains stable and the cooler air can be seen to be clinging to the side walls and not affecting the pupils. This image would be even further enhanced by the movement of the occupants, creating even greater mixing. The reason why the pupils close to the windows appear to generate more heat is because of the air flow through the opening windows. The incoming air sticks to the ceiling and does not initially mix with the plumes generated by the pupils near the windows. It is some metres into the room before the incoming air starts to create a downstream flow, which then mixes with the pupils' heat plumes.

To get an even more detailed insight into the air flow in the classroom other graphics can be used. Figure 4 shows the temperature contoured flow trajectories.
The dark blue colour corresponds to 5°C, which is the temperature that the cold air enters the room. The colder external air is entering via the façade windows and it is then sticking to the ceiling and walls at high level due to the coanda effect and the wind driven pressure created due to the fine control over the window opening distance. The air is then mixing with the heat plumes from the occupants and other internal heat sources and is naturally mixed and tempered by the time it reaches the occupied zone.

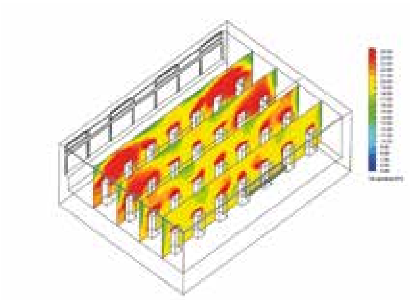


Figure 3 Temperature distribution around the occupants

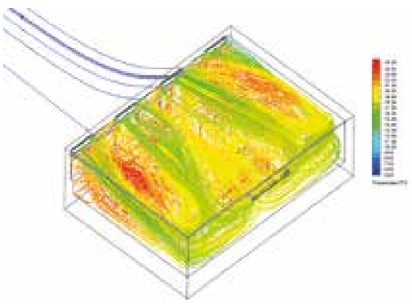


Figure 4 Temperature contoured flow trajectories

Air velocity distribution
Please note that in the velocity distribution images, the dark blue colour represents low air velocities (0.05 m/s) and the red is higher air velocities (0.15 m/s), these must not be confused with temperature.
It has been shown that the temperature in the occupied zone is well tempered before reaching the occupants. However, if the air velocities are too high people would still feel draught. Therefore the air velocity around the occupants has been investigated. The results for the internal air velocity show that the velocities around the occupants are lower than 0.1m/s, which is well below the CR 1752 requirement of 0.18 m/s and the PSBP Facilities Output Specification of 0.3 m/s.

The following figures illustrate in more detail the situation with regard to the air velocities. When read in conjunction with the temperature images above, then a very clear picture of the comfort levels can be established.

Figure 5 demonstrates that the highest velocities are, as expected, at the ceiling level where the windows are open. As with the temperature distribution, the benefit of the coanda effect, due to the high level windows, can clearly be seen.

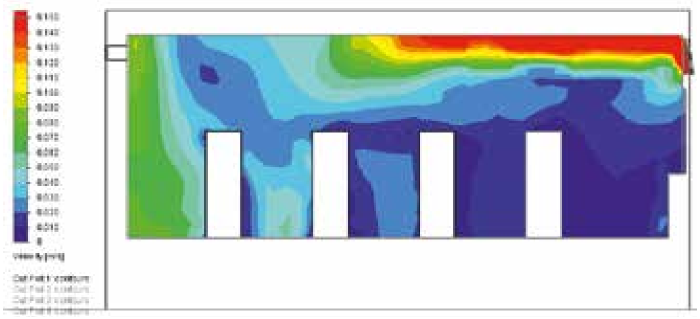


Figure 5 Air velocity distribution for high level tophung outward opening windows

The mixing of air without draught is achieved:
· Cold incoming air mixes with warm internal air at high level.
· The air velocities around the occupants are below 0.1m/s.

In the cross section to the right, the velocity distribution around the occupants can clearly be seen. The air velocities can be considered very low and do not constitute draught.

In Figure 7, the higher velocities (red colour) can be seen in front of each of the four operable windows. The two operable windows in the centre make an air stream that sticks to the ceiling which decreases in speed the further it travels. The development of the air flow generated from the two operable windows on the either side is much more interesting. This illustrates the air is attached to the ceiling and walls but does not reach the occupants located closest to the walls.

The air enters via the four high level façade windows and moves at slightly higher velocities across the ceiling and at high levels along the side walls. In the occupied zone the velocities are well below 0.1m/s.

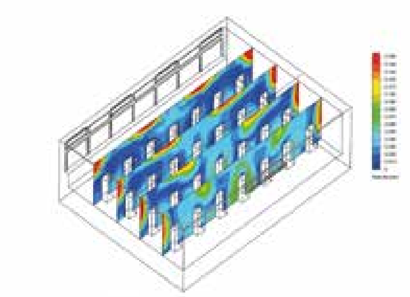


Figure 6 *Air velocity distribution around the occupants*

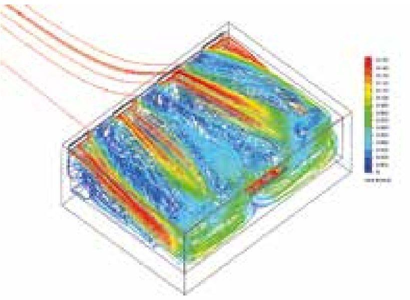


Figure 7 *Velocity contoured flow trajectories*

Conclusion

This whitepaper clearly demonstrates that with precise control and with a well-designed natural ventilation strategy you can provide a satisfactory wintertime ventilation performance. In winter, draughts can be mitigated with fine control, as the cold air (5°C) is sticking to the ceiling due to the wind velocity and the coanda effect. Cold air is not falling down close to the windows. If the vents were opened further, thus providing too much ventilation, or the number of vents was reduced, meaning they would need to open further to provide the same ventilation rate, then there is the risk that the colder air will begin to drop sooner.

It is not correct to say that all windows create a draught. It is incorrectly sized and positioned windows, along with poor control strategies and systems that can cause draughts.

To avoid draught it is important to have the correct sized and positioned windows, along with fine control strategies.

If there are sufficient high level windows and the control system has the ability to control the openings dependent upon the internal demands and the external temperatures and wind pressures then draught issues can be mitigated. Basic control strategies and systems, or manual user control, will not be able to manage these factors sufficiently.

The positive result from this CFD modelling is not just a new theory, it is something WindowMaster can evidence in practice through many hundreds of successful projects delivered over the last 20 years.