the sustainable building association

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Passivhaus ventilation: It's not a lot of hot air

An article for the AECB by Mark Siddall

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If you believe some of the things you hear about Passivhaus, you might think each one was a suffocating prison of stale, unhealthy air, sealed off from the outside world behind locked windows. Mark Siddall, architect and Certified Passivhaus Designer, does a little myth busting and sets some facts straight, before exploring some areas where neither natural ventilation, mechanical ventilation, nor even the Passivhaus standard, have absolutely all the answers.

The basic premise of reducing energy demand underpins the Passivhaus Standard. This concept is relatively straightforward, nonetheless myths abound; particularly with regard to ventilation.

In our temperate climate, in order to satisfy the performance requirements of the Passivhaus standard, 'mechanical ventilation with heat recovery' (MVHR) needs to be installed. The rationale is threefold, firstly its purpose is to provide sufficient fresh air, secondly it is to avoid draughts and discomfort and finally it is to reduce energy demand; without heat recovery, ventilation leads to unnecessary energy demand and can cause thermal discomfort.

In buildings with MVHR, fresh air is drawn in through a heat exchanger, past the stale air being extracted from the building. The heat exchanger is designed so that the exhaust air warms the incoming outside air, before it finally leaves the building. Importantly the two air streams do not mix, thereby maintaining high standards of fresh air supply throughout the home.

In order to circulate the fresh air throughout the home, two low energy fans are used; one on the supply and one on the extract. The fans only consume a fraction of the energy that the system manages to 'harvest' from the stale air. Measurements have shown that they can save more than ten times the amount of energy that they use.

So, those are the basic facts of Passivhaus ventilation. Now it's time to address some of the myths.

"You are not allowed to open the windows in a Passivhaus"

The rumour that you hear surprisingly often is that "You are not allowed to open the windows in a Passivhaus."

This notion is completely unfounded. Imagine a house without windows; four walls and roof, that's it. This is not a positive image but it does allow us to recognise that a window has to perform many essential tasks; it must let air in, light in, it must provide a view, and it must keep the wind and rain out. It must also be capable of being cleaned. If we were not able to open it then it would be crying shame. There is absolutely nothing in the Passivhaus standard that says anything about not being able to open the windows.

It is, I believe, fair to say that during the winter we rarely open windows. But when do we open them? Imagine a fine, fresh winter's day. You've been relaxing, drinking a fresh hot chocolate on a lazy Sunday morning, the sun is streaming in and you get the sudden urge to open the window to experience a little of what is going on outside. You stand there holding the warm mug staring out into the garden and feel the cold air washing over you as you hear birdsong in the distance. It's refreshing. After a while, when you're good and ready, you close the window.

How long did you stand there? Five minutes? Ten minutes? Even if you stood there for fifteen minutes would this wreck the whole energy performance of the building? No – as a proportion of the heating season, how long is a quarter of an hour? Tiny! Even if you were to do this every day it would only be about 1% of the heating season. So of course you can open the windows of a Passivhaus.

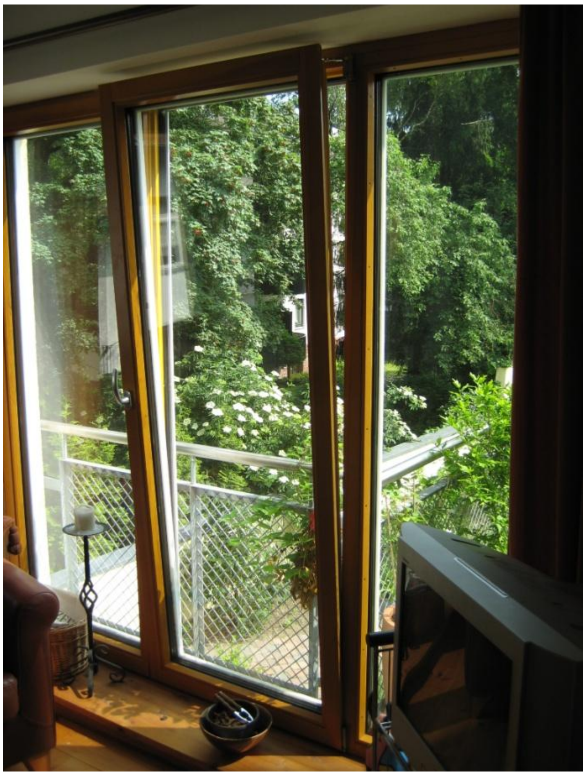

Fig 1. Passivhaus occupants are free to enjoy the scents and sounds of outdoors

If the windows were to be left wide open for long periods in winter, then that could be a problem -- just as it would be for any house - but this is not very likely. After all, most of the time people will prefer to be comfortable.

The more mundane reason for opening windows in winter tends to be to let steam out of a bathroom or kitchen, or to remove cooking smells. This is where the ventilation in a Passivhaus comes into its own: steam and smells are removed automatically – you can even turn the ventilation up to 'boost' when required – so users simply feel the need to open the windows a lot less often during the winter.

As a matter of fact, in warm weather Passivhaus occupants are encouraged to open their windows. In the height of summer it is advantageous to naturally ventilate during the night-time as it offers greater potential for cooling. Then, in the morning, the windows can be closed again, to hang on to the refreshing free coolth inside, while everyone else is sweltering outside.

Passivhaus Buildings Spread Germs and Particulates

This comprehensible concern arises from the fact that people do not know where the air comes from. As the air comes from a pipe people may be anxious that the air could distribute germs within a room; as has happened in office buildings and hospitals in the past. It is at this point that an important difference should be recognised. As was explained at the start of this article, a Passivhaus relies upon fresh air that comes into the house after being cleaned by a filter and warmed up in the heat recovery unit. Only then does it pass through the ductwork and into the rooms before finally exiting the building via the extract and exhaust ducts, never to be seen again. A Passivhaus building does not re-circulate air and therefore does not foster the recirculation germs or the growth of germs within building or the ductwork itself.

This is entirely different to air conditioning where the air is humidified and re-circulated; it is this form of ventilation that has been associated with problems of airborne infection.

Another concern that exists relates to the possible spread of particulates arising from dust or dirt within the ductwork. The primary cause of debris within the ductwork arises during the construction process; this is an issue that is currently overlooked by Building Regulations in England and Wales. Of the 18,000 or so MVHR units installed in UK buildings last year[1]; the majority were not in Passivhaus buildings. While no research has been done into the quality of most installations, the Certified Passivhaus Designers and Consultants have been trained to supervise the construction process so as to maximise the cleanliness of the ductwork. With good standards of quality assurance, ducts will be protected during construction to prevent them being coated with builders' dust; and if they do get dirty then they should be cleaned.

Fig 2. Passivhaus design specifies vapour retardant insulation, to prevent condensation forming inside or outside the ventilation ducts

Crucially, in a Passivhaus, the ductwork between the MVHR unit and the thermal envelope of the house is insulated. The vapour retardant insulation serves two purposes, it prevents condensation and, therefore, mould growth on (or in) these lengths of ductwork, and it also reduces heat losses. All in all if the building is handed over with suitably clean ductwork then, thanks to the use of high quality filters, there is no reason for the ducts not remain clean for the foreseeable future; just as they have at the first Passivhaus homes in Kronsberg even after 20 years.

1 http://www.building4change.com/page.jsp?id=1193

Passivhaus Buildings are Draughty

This concern arises from the fact that when you hold your hand to the air supply grille, air movement can be felt. Research by Olaf Fanger helped to develop our understanding of thermal comfort, and established that the threshold at which discomfort from draughts may be felt is about 0.1m/s. By positioning the air inlets and outlets close to the ceiling it is possible to exploit the coanda effect, whereby the aerodynamics of moving air means that it temporarily clings to the ceiling before gradually falling and mixing with the other air within the room. Measurements in Passivhaus buildings have shown that the velocity of moving air within the normal habitable zone is well below the threshold of discomfort.

Fig 3. Ventilation outlet in a Passivhaus – the air moves over the ceiling before gently mixing with the air in the room

You get constant fan noise, and the ventilation ducts will broadcast your private conversations everywhere in the house

Because of the presence of metal ducts leading to each room some people have worried that noise could be heard between one room and the next. Additionally, there is a concern that noise from the ventilation fans will either annoy people, or worse, lead occupants to turn down the ventilation until the noise stops, resulting in substandard ventilation.

These concerns are very understandable and it should be pointed out that Building Regulations in England and Wales do not impose specific acoustic criteria for MVHR systems. Furthermore in the Netherlands it has been found that there is a tendency to design and install to MVHR systems to suit minimum regulatory requirements rather than standards of good practice, which has resulted in systems with poor acoustic performance (unfortunately there are no similar UK studies). Taken together, these observations do suggest that concerns regarding acoustics could be legitimate. But it is important distinguish between ‘standard issue’ MVHR installations and ventilation installed to the Passivhaus Standard.

First of all in a Passivhaus, the ventilation unit is located in a plant room or another unoccupied space that is away from living, working and sleeping areas. The MVHR unit itself is well insulated and satisfies strict acoustic performance standards established by the Passivhaus Institute so that is it possible to achieve less than 35 dB(A) in non-habitable rooms. There is also a design requirement limiting the break out noise to <25dB(A) in habitable rooms[2]. To achieve these performance targets acoustic attenuators (silencers) are fitted to the supply and extract ductwork to prevent the fan noise from travelling through the ductwork, and there are also attenuators between each room to prevent telephonic transfer.

[2] 25dB(A) is comfortably lower than the 30dB(A) level set by the World Health Organisation as a minimum noise level to allow a good night’s sleep.

The importance of good standards of quality assurance for ventilation cannot be overlooked. It could be argued that neither the UK nor, until recently, the Dutch Building Regulations[3] have got to grips with the finer aspect of MVHR systems. This may leave people (in non-Passivhaus buildings) with MVHR that is installed without the benefit of adequate acoustic standards; the consequence being that, so as to reduce the noise to an acceptable level, they turn the fan speed down and unwittingly end up under-ventilating their homes. In this respect the Passivhaus standard may offer a beacon of light that shows what can be achieved with the correct attention to detail and robust quality assurance methodologies.

Dry air

It is said by some that the air is a Passivhaus is dry.

Well, certainly the air in a Passivhaus is generally drier than the air in a house with poorer ventilation; and generally this is a good thing. Excess moisture in homes and other buildings has a direct link to the growth of moulds, the flourishing of dust mites, and the presence of unpleasant pests such as silverfish, clothes moths, and woodworm. Excessive dampness indoors can harm the health of the occupants, the fabric of the building, the furniture and the contents.

Many everyday activities - cooking, showering, drying clothes, drinking coffee, washing dishes, and watering plants add moisture to the air. In an under-ventilated home the moisture builds up, (especially in winter when windows are kept shut to keep out the cold) and can quickly reach undesirable levels. A building may suffer condensation on cooler surfaces such as windows and doors, and on surfaces ‘insulated’ from the room’s heat, for instance behind a cupboard, or under a carpet. The accumulating damp may then lead to the problems described above.

A comfortable and healthy range for relative humidity is usually between 35% and 60%.

Now let’s think about what happens when supplying adequate fresh air during the winter. Cold air contains relatively little water vapour. So on a bitterly cold winter’s day, even if the relative humidity outside is 80%, if the temperature is -10^{o}C outside this would mean that there would be only 2.2g of moisture per 1m^3 of air.

Now imagine that we have a 1m^3 glass box with a hygrometer (for measuring relative humidity), and a thermometer. If we fill that box with this fresh, but cold, outdoor air and bring it into a warm room what will happen? After some time the thermometer now reads 20^{o}C and the box still contains 2.2g of moisture, but the hygrometer now reads 13% relative humidity. In other words, that 2.2g is only 13% of what the air could hold at that temperature – in other words, it is dry. Only on a foggy day, when the outdoor temperature is at about 8^{o}C and the indoor temperature is 20^{o}C, the air supplied into the home would have a relative humidity of about 50%.

Neither of these conditions have anything to do with the Passivhaus standard – it is simply a matter of physics; if you are adequately heating and ventilating a building, but indoor moisture production is low, the indoor air may get too dry; this applies to any building regardless of ventilation strategy. But in reality the requisite ventilation is only bringing in a bit of fresh air at a time, which is mixed with the existing air within the house; which of course contains the moisture given off by day to day life.

[3] As of 1st April 2012 Dutch Building regulations will impose an acoustic limit of 30dB(A) for habitable rooms.

Measured results from a quality assured Passivhaus building[4] shows that the average relative humidity remains within the threshold of comfort and above 35%. For instance figure 1 below shows a home with a balanced ventilation system. The room temperature was approximately 21°C throughout January to March 2010, meanwhile during the winter the external temperature ranged

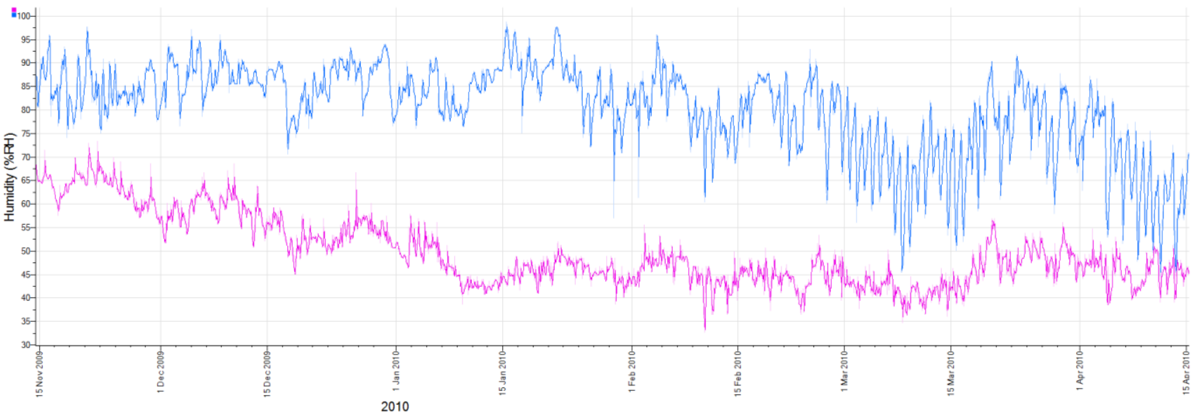

Fig 4. The indoor and outdoor relative humidity over a five month period during 2010/2011 at Grove Cottage

between –6°C and 13°C.

The indoor relative humidity (shown in magenta, external in blue) fluctuates over time; for very brief periods the relative humidity fell to less than 35%RH (about 5hrs i.e. less than 0.05% of the study period). In general the relative humidity remained between 40% and 50%RH. A relative humidity below 45% is ideal for killing dust mites and thus reducing the risk of asthma.

The Passivhaus standard explicitly sets out to ensure the best possible indoor environment for occupants, by ventilating the whole building properly, to remove excess moisture and any other indoor pollutants. The ventilation of a Passivhaus must be capable of complying with DIN1946 and is therefore designed to be capable of supplying at least 30m^3/person per hour.

In order to deliver adequate indoor air quality a certain number of air changes are needed per hour. With natural ventilation, due to the vagaries and inconsistencies of fluctuating wind speeds, window/trickle vent utilisation etc, sometimes under ventilation will occur and at other times over ventilation will occur. Balanced ventilation (MVHR) on the other hand provides fresh air in a more consistent and more reliable fashion. For this reason it may be regarded to have a better “ventilation efficiency” than natural ventilation. In practice this means that the ventilation rate can be reduced to a slightly lower level in order to achieve the same level of indoor air quality.

The lower RH that is reported in some homes with MVHR, compared to those with natural ventilation would, to my mind, appear to suggest one of two things (though both conditions may apply in reality). The first is that the ventilation rate (to, say, DIN or Building Regulations Part F) may not currently take into account the ventilation efficiency of balanced ventilation, and secondly that the volume of fresh air that has been set by the standards in order to remove pollutants is greater than is desirable for optimum RH, at least in cold weather.

[4] Grove Cottage meets the Passivhaus Institutes retrofit standard known as EnerPhit. Monitoring data courtesy of Simmonds Mills Architects

In relation to the greater ventilation efficiency of balanced ventilation, it is interesting to note that in practice, for residential Passivhaus buildings, an air supply of 23.1m^3/person per hour has been found to deliver adequate indoor relative humidity and indoor air quality[5]; this is the reason the Passivhaus Planning Package (PHPP) makes the assumption of reducing the ventilation rate to 77% of the requirements of DIN1946[6] for standard occupancy.

If however it is the case that, under certain scenarios, the full 100% of DIN 1946 is needed to remove pollutants then logically this leads to the argument that we should strive to improve IAQ by reducing the TVOCs and other emissions from materials.

And lastly, the higher reported relative humidity that is sometimes found in naturally ventilated homes may really indicate that the intermittent ventilation in these buildings is not always adequate for providing fresh air of consistent quality; if enough outdoor air was coming in and being heated, the buildings would be drier.

Whilst there does not appear to be any specific conclusion that can be drawn at this time, what all this analysis and conjecture serves to highlight is that the fact that ventilation is an important issue and deserves more attention than it generally receives.

In the mean time building occupants who find that their sinuses, or eyes, get a little dry in very cold weather have a number of choices that could be used to address any discomfort. There are low and 'high' tech options. Vaporisers, whilst using the same amount of energy as the low tech approaches, require electricity for operation and therefore result in higher carbon emissions, and have filters that should be regularly cleaned so that they do not foster biological growth and then spread germs. The low tech solutions include watering the house plants or using atomisers, which rather than drawing power, raise the humidity and can cool the air instead.

Another low energy option is to temporarily reduce the ventilation rate during the coldest weather. However, here we run up against the issue of failing to adequately remove the airborne chemical emissions arising from the materials and furnishings within the home. Lower ventilation rates – in any building - may unduly compromise indoor air quality. So there is no easy solution to this dilemma.

Finally you could reduce the indoor temperature and as a consequence increase the indoor relative humidity by a margin – however this would have limited impact.

Remember these choices simply arise from the physics of providing fresh air and are independent of the specific ventilation strategy, though of course they do depend on the ventilation *rate*.

So, if we are troubled by dry indoor air in winter, we shouldn't really blame the fact that a house has a ventilation system installed, which is just doing its best to keep us healthy - but perhaps we should look instead at how we can reduce indoor air pollution from finishes and furnishings so that one day it might be safe to ease down the ventilation rate, and thus increase the indoor relative humidity during cold weather.

[5] Protokolland Nr. 23, Einfluss der Luftungsstrategie auf die Schadstoffkonzentration und ausbreitung im Raum, Passivhaus Institut, July 2003. (document in German, translated title: The influence of the ventilation strategy on the pollutant concentration and propagation in the room)
[6] http://forum.passipedia.org/viewtopic.php?f=14&t=66#p210 and Passivhaus Planning Package (PHPP 2007).

Conclusion:

Whilst this article is far from exhaustive I hope that this quick romp through ventilation has served to distinguish the Passivhaus standard from the general mêlée of justifiable concerns that exist with regard to the rest of the construction industry, whilst also clarifying and dispelling a few of the rumours and myths that seem to perpetuate themselves. If you wish to continue this debate please contact me via the AECB Forum at http://www.aecb.net/forum/index.phptopic,3605.0.html

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