Breathing Buildings

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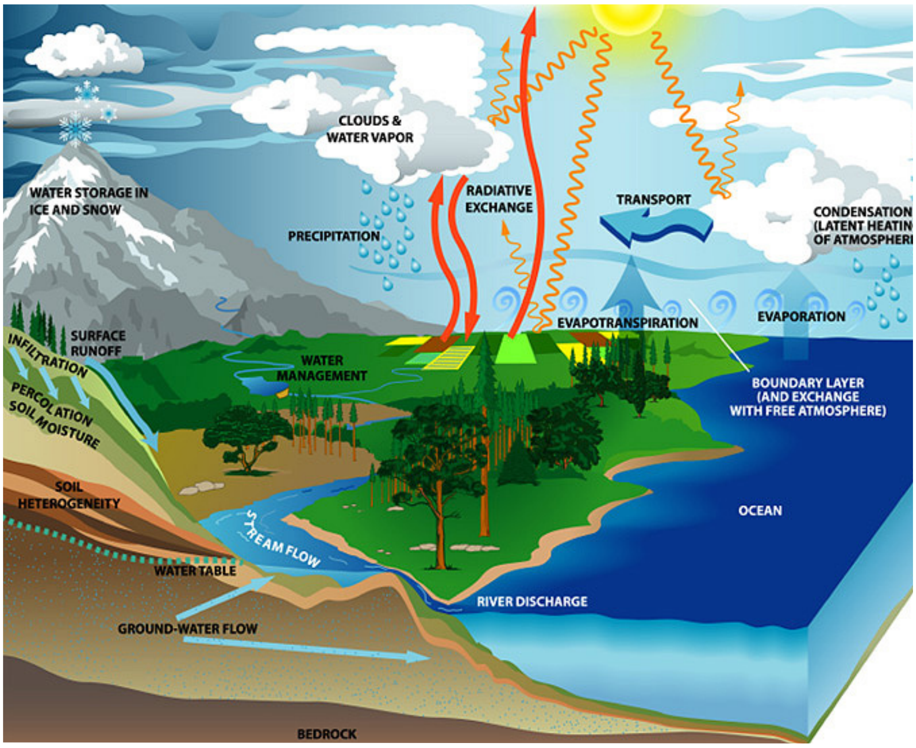
In the course of researching a self-build project, many people will have come across the term "Breathing Walls". It sounds nice, sounds natural, but is it a good idea? Chris Morgan offers some thoughts on why it might be worth considering...



The Water Cycle

I expect we all remember images of the water cycle from school. There was a rather idyllic landscape of mountains, dropping to foothills, followed by a few fields in the lowlands, a beach and the sea, with the sea bed dropping away in section to the deep ocean. A stream in the hills became a meandering river in the lowlands and we all understood how this river and the groundwater below took water from high ground back to the sea. Above were clouds formed from evaporation over the humid oceans, driven against the hills by wind and shedding their rain and snow to complete the cycle.

I'm sure I didn't appreciate it at the time, but I now have a strong sense of this glorious swirl of moisture on a grand scale, constantly on the move, bringing life to the soil and plants, cleansing and thirst quenching water to us, shade against the sun, and home to countless billions of aquatic lives.

But the overriding impression is of movement; constant movement of moisture through and across the whole of nature, bringing and supporting life, wherever it goes.

Modern Houses

Cut rather abruptly to modern houses. Here, it almost seems as if we have turned our back on the natural sweep of moisture all around. Moisture, it seems has become a problem which we need rid of as quickly as possible.

Let me explain. In almost all modern buildings, we dare not let moisture into the fabric of our buildings. If we did, they could rot, so we install polythene membranes (or an equivalent) to all internal surfaces of our houses to make sure moisture cannot get in. We're also concerned about moisture in the air. People and their activities in houses generate moisture, amongst other things, and an excess of this can lead to condensation and mould, so we usually install mechanical ventilation in the worst areas – kitchens, bathrooms and utility rooms – to extract the moisture as soon as it is generated.

Not exactly 'going with the flow' of the great movement of moisture across the landscape, but as far as most people are concerned, this is problem solved. Certainly that is how the Building Regulations see things, but there are several nagging issues which remain which I will discuss in due course.

Traditional Houses

Of course it wasn't always like this. What happened before we invented polythene and electric driven extract fans to protect us from all this moisture?

The walls of traditional houses in the UK and Ireland tended to be built of stone or brick, earth and timber. Sometimes covered in lime renders and washes, often not. Rarely if ever did these houses have damp proof courses, but they all had plenty of ventilation; wanted and unwanted, from openings, gaps and cracks, and, significantly, from chimneys and fireplaces. Moisture got into the walls and the air, but it was generally dispersed.

Now, I am not saying that there wasn't an issue with damp in many of these houses, nor am I unaware that living standards have improved somewhat! But I am saying that in terms of moisture, these buildings were generally in equilibrium. This is an over-simplification but it is borne out by developments in understanding generally in the care, repair and restoration of older buildings.

We appreciate now that placing modern plastic, acrylic and cement based renders and coatings on traditional buildings can serve to worsen, rather than improve performance, and indeed in many cases can cause serious damage to the building fabric. We have learnt, in a nutshell, that moisture moved around and through traditional buildings. Whether this was understood and designed for at the time we cannot necessarily say, but we can say that if we employ modern responses – based on blocking the passage of moisture where it suits us – it tends not to work.

Breathing Buildings

To this appreciation of traditional buildings we can add the growing body of research and understanding into modern breathing construction.

Breathing construction has got nothing to do with air movement, it is all about the movement of moisture: of water and water vapour. The correct term is 'moisture transfusive' construction, meaning that moisture moves through the construction, but that term never caught on. I've always felt that 'sweating' construction would more accurately describe the process since it is among other things about releasing moisture through a vapour permeable 'building skin' and also avoids the confusion with air movement, but strangely that term never caught on either! So we are left with a potentially confusing, but appropriately 'natural' sounding term which will have to do...

Three key things characterise the issue of breathing construction: vapour permeability – the movement of water vapour through materials and constructions, hygroscopicity – the ability of materials to absorb, store and release vapour, and capillarity – the ability of materials to absorb, store and release water as liquid.[1]

It has to be said that these material characteristics, and the effects of moisture generally within buildings are still woefully unappreciated within the design and construction industries. Yet for those, like myself, who became interested first because of a vague sense that understanding these would lead to more environmentally benign buildings, what became clear was that this understanding leads not only to significantly 'greener' construction, but also to better durability, much less risk of decay and damage, better air quality, greater comfort, greatly reduced waste in the long term and a host of other incidental benefits which lead, in short, to a far higher performance.

A good way to understand these advantages is to study the conventional timber frame, and the 'breathing' alternative.

Conventional Modern Timber Frame Walls

Modern timber frame buildings have to utilise vapour barriers internally because if they didn't, moisture could get into the building fabric. Moisture would tend to get into the fabric because vapour pressure is generally higher within the building than outside, so the moisture moves under pressure outwards. (Extract

This image shows what happens when the Electrician pulls their cables through from within the wall to be terminated at a switching point. The penetration of the polythene vapour barrier which can be seen is impossible to seal completely and thus the protection of the building fabric is compromised at this point.

ventilation serves to reduce this outward pressure and is perhaps the main mechanism preventing moisture ingress into the walls, but more of this later.) Once this moisture worked its way toward the outer layers, it could cool and condense. This is known as interstitial condensation. Since most modern timber frames use plywood or a similarly vapour-impervious board on the outside of the frame, this moisture cannot get out, and so it could stay inside the frame eventually leading to decay of the timbers.

Clearly we cannot let this happen so an impervious membrane is used internally to prevent moisture getting into the wall. And just to be on the safe side, the timber is usually treated with chemical preservatives.

As long as the vapour barrier works, then this is fine. Generally the vapour barrier is fixed directly to the studwork once the insulation has been installed just behind the plasterboard. It is generally overlooked that the timber is not always dry when installed and that once the internal vapour barrier is installed, there is no way of this timber drying out.

But more importantly what happens when the Electrician does his second fix? Light switches, sockets and all sorts of other fittings are connected through this critical membrane, socket boxes are cut through the plasterboard (and polythene) and it is genuinely difficult – even assuming that the intention was there – to carefully seal each and every penetration. It is common, if not ubiquitous that vapour barriers are penetrated dozens if not hundreds of times on each build.

A 'Breathing Wall' under construction. The hygroscopic recycled cellulose insulation can be seen being pumped into position in the ceiling and already installed in the walls. The internal bracing and sheathing board is in place in the ceiling, this acts as both the vapour check and air barrier for airtight construction.

Several Designers have come to believe that this is not a robust solution because you are effectively creating a problem and then having to solve it using a relatively vulnerable element, whilst relying on ventilation (which can be sealed off or switched off by Occupants any time, uses energy and requires maintenance) to prevent any outward pressure.

One solution to the vulnerability of the vapour barrier is to provide a service void whereby a void is created behind the plasterboard, but crucially in front of the vapour barrier, so that all the pipes and cables can be routed around the building without having to penetrate the membrane. This dramatically improves the long term robustness of the detail, and incidentally also improves the flexibility of the building long term since alterations are much simpler to make, but it also introduces another layer, creating less internal space, more work and cost, so it is not common.

The Breathing Alternative

Breathing wall construction starts with a straightforward proposition; that you make the outer sheathing board vapour permeable, so that if moisture gets into the wall, it is relatively easy for it to pass safely through the permeable outer layer to the ventilated cavity. There are a few options of external sheathing available, but most consist of relatively soft woodfibre boards. Any sort of external skin can be used as long as there is a ventilated cavity between, so there is no limit to how the building will look from the outside.

Of course that external sheathing was performing a valuable function. Apart from keeping the insulation in, it was also acting to brace the wall structurally, transforming a series of sticks into a strong 'plane' of structural resistance, so if we replace this we have to still perform this bracing role. Partly this can be achieved with the woodfibre boards, but often it is achieved by making the internal sheathing strong instead.

Breathing walls still need to have some resistance to moisture on the inside face and the accepted rule of thumb is that the vapour resistance of the internal layers must be at least five times that of the external sheathing. Five times harder for the moisture to get in from the inside than it is to get out the other side. Plasterboard and OSB will generally suffice as internal linings, but there are of course many other options, so again there is no need for the aesthetics of the wall, floor or roof to be affected.

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In the case of traditional buildings – or modern earth or straw bale buildings – this 5 to 1 ration tends to be ignored because experience, in the case of traditional buildings, and condensation risk analysis in the case of the organic modern counterparts, tends to show that there is no risk of interstitial condensation. Even where there might be a theoretical risk, the sheer mass of hygroscopic material and vapour permeability of the construction probably means the construction is not at risk, but it begs the question why the 5 to 1 ratio, and it is certainly likely that in many cases this is not needed. Some research[2] has shown that the 5 to 1 ratio is a sensible precaution, and one which when modelled tends to show acceptable condensation risk.

An often overlooked but important aspect too is that of the insulation. Ideally, you want a hygroscopic insulation; which safely absorbs and releases moisture in its vapour form. Synthetic insulation like glass and mineral fibres, and polystyrene forms cannot do this, whereas natural insulants like cellulose, sheepswool, hemp, flax and so on all do. Hygroscopic insulation can safely store and buffer the moisture levels in the wall, to an extent without affecting their insulative properties, and further protecting the timber frame from decay risk. Most practitioners who routinely specify breathing walls can therefore forego chemical treatments of the timber frame because it is not at risk of decay any more.

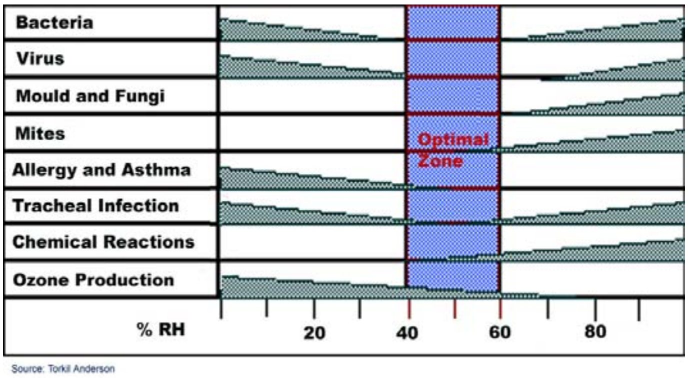
Modern breathing walls, using timber frames, woodfibre boards and natural insulations are now quite common in the UK and available from several suppliers.[3] By way of summary breathing walls have the following advantages over conventional timber framed constructions:

- being intrinsically protected from decay, they are a lower risk option, and less susceptible to poor practice
- less at risk in the event of a failure or cessation of extract ventilation
- The hygroscopic insulation gives increased tolerance and durability of the system
- the timber frame can safely be left untreated, reducing chemical loads on builders and occupants
- the natural insulations have lower embodied energy than mineral fibre options
- the natural insulants, woodfibre boards and untreated timber frames are all biodegradable and can be safely composted at the end of their service life, helping to achieve a zero waste building solution

Moisture Mass

Whilst the advantages of breathing walls over conventional timber frame walls are clearly understood, there are a number of other potential advantages of working with vapour permeable, hygroscopic and high-capillarity materials which are at present only minimally understood, but which offer considerable potential benefits.

Perhaps one of the most exciting of these is the capacity of breathing construction to act as a passive buffer to the inside air, regulating and controlling internal relative humidity (rh). This might not seem like a big deal to some, but it is well known amongst some Researchers, Ventilation Engineers and a few others that it is important – for occupant health and the durability of buildings – to maintain relative humidity of the air in buildings within a band between about 40% to 60% ideally. See Diagram.



This diagram is based on the 'Sterling Bar Chart' introduced in "Indirect Health Effects of Relative Humidity in Indoor Environments" by Anthony V. Arundel, Elia M. Sterling, Judith H. Biggin and Theodor D. Sterling. Environmental Health Perspectives, Vol. 65, (Mar., 1986), pp. 351-361.
This shows the unwelcome increases in various health risks at both low and high extremes of relative humidity. Healthy internal air can be maintained by keeping rh within 10% either way of 50% as shown.

Normally in larger buildings this control is achieved by air conditioning, through coolants or dessicants. In houses, there is rarely any control except the rather blunt tool of extracting air from kitchen and bathrooms etc., regardless of the humidity of the incoming air which replaces it.

Work by Tim Padfield[4], Gernot Minke[5] and others[6] has shown conclusively that hygroscopic materials exposed to the internal air can absorb and desorb (release) moisture vapour in the air and in this way passively balance the relative humidity to create a healthier internal environment without the use of electricity for fans, coolants, dessicants and so on.

Clay / earth and end grain of timber are the most effective hygroscopic materials, but all materials will have some effect, though this can be reduced by impervious coatings.

Importantly, this capacity is severely reduced by ventilation. If vapour is being extracted with air at a sufficiently high rate, the capacity of hygroscopic materials to buffer the relative humidity is largely lost. Currently the issue is academic only as ventilation is the only recognised method for dealing with moisture, and the evidence to support hygroscopic buffering not sufficiently known.

But it doesn't take much imagination to see that with greater investigation, it might be possible to use hygroscopicity to passively buffer humidity, reducing our reliance on ventilation. Extract ventilation uses a good deal of electricity, so of course there would be direct energy and cost savings. Furthermore, as buildings become increasingly airtight and insulated, ventilation losses become the main cause of heat loss, so we make further energy and cost savings too.

Most houses currently have no control of relative humidity except the extraction of excessively moist air. This probably deals with the highs of rh, but what about the lows? It is well known that in pulling in cold air and heating it – as every household invariably does during the heating months, we lower the rh of the incoming air, and there are several experts who believe that we are living with excessively dry air for too much of the time. passive buffering could help alleviate this, storing moisture safely and releasing it when the relative humidity drops.

And there is also the issue of thermal mass. We know that thermally massive construction can absorb and store heat, letting it out when the surrounding air is colder. Designed correctly, this can reduce heating costs and buffer both uncomfortable highs and lows of temperature.

But hygroscopic materials do the same, partly through the movement of moisture in and out of them. We know that water stores heat well (hence hot water bottles) so it should come as no surprise, but the science is not widely understood, and the applicability of this not widely appreciated. It is partly speculation therefore, but I can see a future of housing in which the careful design of hygroscopic materials not only buffers relative humidity, providing healthier, more, comfortable and energy efficient housing, it also helps buffer temperature, again reducing energy costs and increasing comfort levels.

There are many hurdles to overcome before we fully understand the issue. We know the different levels of hygroscopicity and capillarity of different materials, but it is not just about these characteristics, but about the rate of moisture absorption, the thickness needed for different required moisture storage periods (daily or monthly, for example?) We know that none of this works well without good airtightness. But that issue is still finding its feet in the industry with monitored levels still hopelessly low in most cases.

There is the issue of decrement delay and the ability of denser insulants, like woodfibre to help with cooling of lightweight structures where lighter and non-hygroscopic insulants like mineral wool cannot.[8] Neither do we know what are the appropriate levels of ventilation in respect to hygroscopicity; we'd like to safely reduce ventilation rates, but no-one is suggesting we cut out ventilation. Altogether. There are lots and lots of unanswered questions as things stand.

What we are looking at is a proper understanding of moisture movement within buildings. It's a potential win-win situation; we can reduce the risks of unhealthy, mould-prone and at-risk construction, whilst also providing increasingly energy efficient and comfortable homes.

I know it seemed far fetched to contrast the grand sweep of moisture moving across the landscape to building construction, but I hope to have shown that through a better understanding, we can safely re-introduce moisture movement around and through our houses to huge potential environmental, and personal advantage, re-locating us - at least in this respect – back in the natural cycle of things.

1. For a more detailed description of these, and more background to this whole issue, refer to Neil May's description of breathing construction which can be downloaded free from http://www.natural-building.co.uk/how_to_build_sustainably.htm
2. Eg. 'Moisture Performance of Building Envelopes with No Plastic Vapour Retarder in Cold Climates', Proceedings of Healthy Buildings 2000, Vol 3, Carey J Simonson & Tuomo Ojanen, Technical Research Centre of Finland, VTT Building Technology, Finland
3. Eg Natural Building Technologies – www.natural-building.co.uk, Construction Resources - www.constructionresources.com/, Excel Industries - www.excelfibre.com/building/index.html,
4. Tim Padfield: see http://www.padfield.org/tim/index.htm and for one of the more relevant papers: http://www.padfield.org/tim/cfys/phd/phd-indx.php
5. Minke G, 'Earth Construction Handbook: The Building Material Earth in Modern Architecture', WIT Press, Boston 2000. ISBN:1-85312-805-8
6. NordTest Workshop on Moisture Buffer Capacity at the Department of Civil Engineering, Technical University of Denmark, August 2003, ISBN 87-7877-129-3
7. See, for example a Dutch experiment described in http://vikinh-house.ie/decrement-delay