# Breathability Matters

## Why the Kingspan White Paper is seriously misleading

**Introduction:**

In March 2009 Kingspan produced a White Paper on Breathability subtitled: A study into the impact of breathability on condensation, mould growth, dust mite populations and health. On the front page was a picture of a red herring. The executive summary concluded "**Breathable constructions and the breathability of insulation products** are therefore at best a side show, in reality they are **a complete red herring** in the avoidance of surface condensation, mould growth and exacerbated dust mite populations." An article in the autumn 09 issue of Green Building by Phil Heath refers to this document and re-iterates its main theme.

In this article we accept that the basic data provided by Kingspan was mainly correct; furthermore the basic assertion that vapour open walls (which Kingspan call "breathable walls") are not an effective way of transferring moisture from the inside of buildings to the outside when compared to bulk air exchange (ventilation plus air leakage) was also correct.

However the argument itself is entirely wrong in asserting that breathability is not important for the prevention of mould growth, dust mite populations and other sick building syndrome. What Kingspan and their consultants have done is set up a false target (the use of vapour open constructions to convey moisture to the outside of buildings) which has been easy to knock down, and in doing so have attempted to undermine all arguments about breathability. This is not only misleading but it is also dangerous for building and occupant health, and as such is highly irresponsible.

**Where breathability matters:**

There are two areas where breathable conditions are vital. These are

- Fabric health, particularly in situations of building faults
- Human health through the prevention of moulds and through the buffering of internal relative humidity

This article will show how different materials in common constructions can have a very different effect according to their "breathable" qualities. It will deal only with wall situations, but equally applies to roof situations (where the use of "breathable" membranes and sarkings is now standard practice across the industry).

Breathability is about moisture in buildings. This term was established some while ago by in the historic building sector and is used in all parts of the industry. Kingspan themselves use the term in their literature in certain build ups. It is important to understand however that breathability does not just mean vapour permeability. As is well understood by experts in this field there are three main qualities in regard to breathability. These are

- Vapour Permeability - the way a material allows water vapour to pass through it, measured as vapour resistance(r), in MNs/gm
- Hygroscopicity - the way a material absorbs and desorbs water vapour as the relative humidity changes, measured by the change in water content (as a percentage of the mass) in a material when stabilised (Equilibrium Moisture Content) after a change in relative humidity, typically from 50% to 85%. The speed of absorption of moisture is also very important.
- Capillarity - the way a material absorbs water as a liquid, measured as the amount of water absorbed by one surface per m2 per hour (w).

A typical chart of values of common and natural materials is as follows:

| Material | Vapour Permeability (r) | Hygroscopicity (increase in moisture/mass at 20º C from an RH of 50% to 85%) | Hygroscopic capacity Density x Increase Kg/m3 | Speed of hygroscopic take up | Capillarity w $kg/m^2h^{0.5}$ |
|---|---|---|---|---|---|
| Cement plaster | 100 | 2 | 40 | Slow | 1? |
| Lime plaster | 75 | 1.75 | 28 | Medium | 1? |
| Clay plaster | 40 | 3 | 36 | Fast | 2? |
| Gypsum plaster | 50 | 0.5 | 5 | medium | 5? |
| Concrete | 500 | 2%? | 40? | Slow | 1.8 |
| Fired Clay Brick | 50 | 0.1% | 1.7 | Medium | 25.1 |
| Unfired Clay Brick | 40 | 3% | 52 | Very Fast | 2 |
| Spruce transverse | 200 | 9% | 54 | Slow | 0.2 |
| Spruce end grain | 200 | 9% | 54 | Fast | 1.2 |
| Plywood | 500 | 9%? | 54 | Slow | 0.1? |
| Mineral wool insulation | 5 | 1% | 0.1 | Medium | 0.1? |
| Expanded polystyrene insulation | 150 | 0% | 0 | N/A | 0.2? |
| PU/PI without foil | 300 | 0% | 0 | N/A | 0.1? |
| PI/ PU Insulation with foil (effective) | > 10,000 | 0% | 0 | N/A | 0 |
| Woodfibre insulation | 25 | 9% | 18 | Fast | 0.5 – 2 |
| Cellulose insulation | 25 | 9% | 4 | Fast | >10 |
| Flax/ hemp/ sheepswool insulation | 5 | 9% | 2.25 | Fast | 1 - 2 |

As can be seen there are very different qualities in different insulation materials. Mineral wool for example is very vapour permeable (low resistance), but has very little hygroscopic or capillary qualities. PU/PI and EPS have greater vapour resistance, and no effective hygroscopic or capillary qualities at all. PU/ PI insulation with foil is effectively vapour closed. Natural insulations are all vapour open, highly hygroscopic and with varying capillary qualities. You will notice that in regard to hygroscopicity the absolute amount of water that can be absorbed by any material is dependent both on its changing Equilibrium Moisture Content and also the density of a material. Dense materials can take in much more moisture from a room, so that the effect will be actually to reduce humidity levels in a room or micro climate. Speed of absorption is also critical in this process of moisture buffering (see below for more on this).

All of these qualities must be taken into account in any understanding or modelling of the way that moisture interacts with buildings. The most advanced and well tested modelling programme for moisture in buildings and construction build ups is the WUFI programme from the Fraunhofer Institute in Germany. Most of the calculations shown in this article are modelled using this programme. It must be clearly acknowledged that this kind of modelling is only a guide to what happens, but it is backed up by material and construction testing and by years of evidence, particularly in historic buildings, through the work of organisations such as the Society for Protection of Ancient Buildings and English Heritage, where the principles of breathability are used not only for the protection of building fabric health, but actually to remove pathological problems such as dry rot and death watch beetle.

**Timber frame construction and breathable materials:**

The importance of breathable constructions is acknowledged in German Building Regulations in relation to Timber Frame construction, in that vapour open constructions do not require timber treatment (except in the sill plate) whereas in vapour closed constructions all timbers must be treated (as they are in the UK). Why is this?

The reason is that if moisture gets into a non-breathable timber frame construction, then because it cannot get out, it will cause decay of the timber frame if the moisture content of the wood goes above 20%. This is the biological tipping point for untreated timber.

Moisture can and does get into a timber frame wall construction through a number of mechanisms:

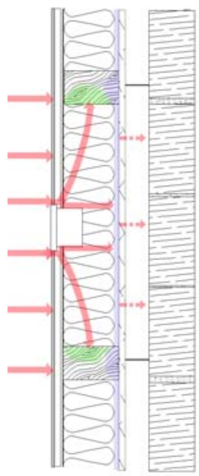
1. from rain during the construction process
2. from rain through the junctions at openings (windows and doors)
3. from rain through poor roof/wall and gutter detailing
4. from rain splash and ground moisture at the base
5. from moisture from within the building through penetrations into the wall due to poor airtightness caused by bad application of, or poor quality of, the airtightness layer, service penetrations, alterations to wall etc.

In fact there are a lot of ways for water to get into the construction over the life time of a timber frame building, which has a “design life” of 60 years, but in reality needs to last for over 100 years (the current average life of buildings in the UK).

So what happens if moisture does get into breathable and non breathable timber frame constructions? How much moisture is necessary to create problems?

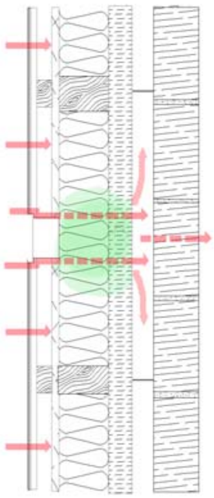
Below we compare two constructions for timber clad timber frame. The first is a standard 89mm timber frame construction using mineral wool insulation infill.  The main factor is that the OSB board is on the outside of the frame and a vapour barrier on the inside.  In the second construction the OSB is on the inside and woodfibre board (60mm Pavatherm Plus is on the outside). The infill insulation is Pavaflex woodfibre but could be any natural fibre insulation, although this is less relevant than the external woodfibre board and the design.  The constructions have approximately the same U values.

In order to explain visually how the 3 different breathability qualities of materials work in construction build ups, the following legend has been created:
Red= vapour movement
Blue = liquid water (as water penetration or condensation)
Green = hygroscopic action



*Standard timber frame construction with OSB on the outside of the frame and polythene vapour barrier and plasterboard on the inside.  Internally full filled with mineral wool*

Water penetration shown through punctured membrane (ie socket) leads to take up of water by timber and condensation on the cold side.  Alternatively water could penetrate behind the OSB into the frame over time through poorly detailed and constructed openings leading to the same condensation issues.



*Breathing timber frame with OSB on the inside of the frame and woodfibre sarking board on the outside. Internally full filled with a natural fibre insulation.*

Water vapour penetration from the inside is more difficult due to service void, but if a penetration is achieved through OSB (ie socket or fault) this will lead to take up of vapour by hygroscopic insulation and transmittance through structure by the hygroscopic and vapour open sarking board. Similarly rain penetrations as above could happen from external openings, but will be drawn away from the structure by the breathability of the materials.

For the purpose of assessment we put three different timber clad timber frame constructions into the WUFI dynamic moisture modelling programme and used the meteorological data from London (mild exposure, Driven Rain Area 1) and Swansea (very severe exposure, Driven Rain Area 4), selecting the most exposed elevation. These constructions were:

**Standard Construction 140mm stud** (inside to out)
12.5mm Plasterboard and skim
Vapour Control Layer
140mm Timber studs full filled with mineralwool insulation
9mm OSB
40mm vented cavity
20mm of timber cladding

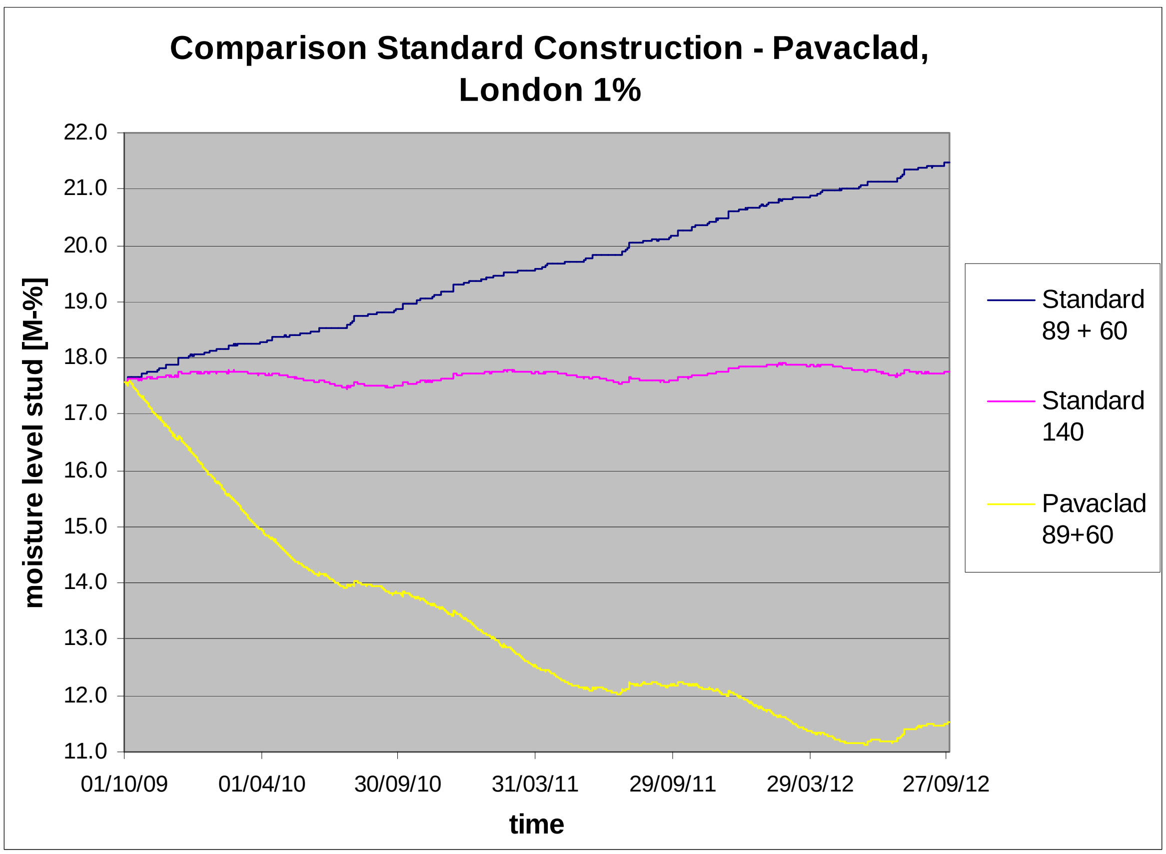
**Standard Construction 89mm stud plus 60mm PU**
12.5mm Plasterboard and skim
Vapour Control Layer
89mm Timber studs full filled with PU insulation
9mm OSB
100mm PU insulation
40mm vented cavity
20mm of timber cladding

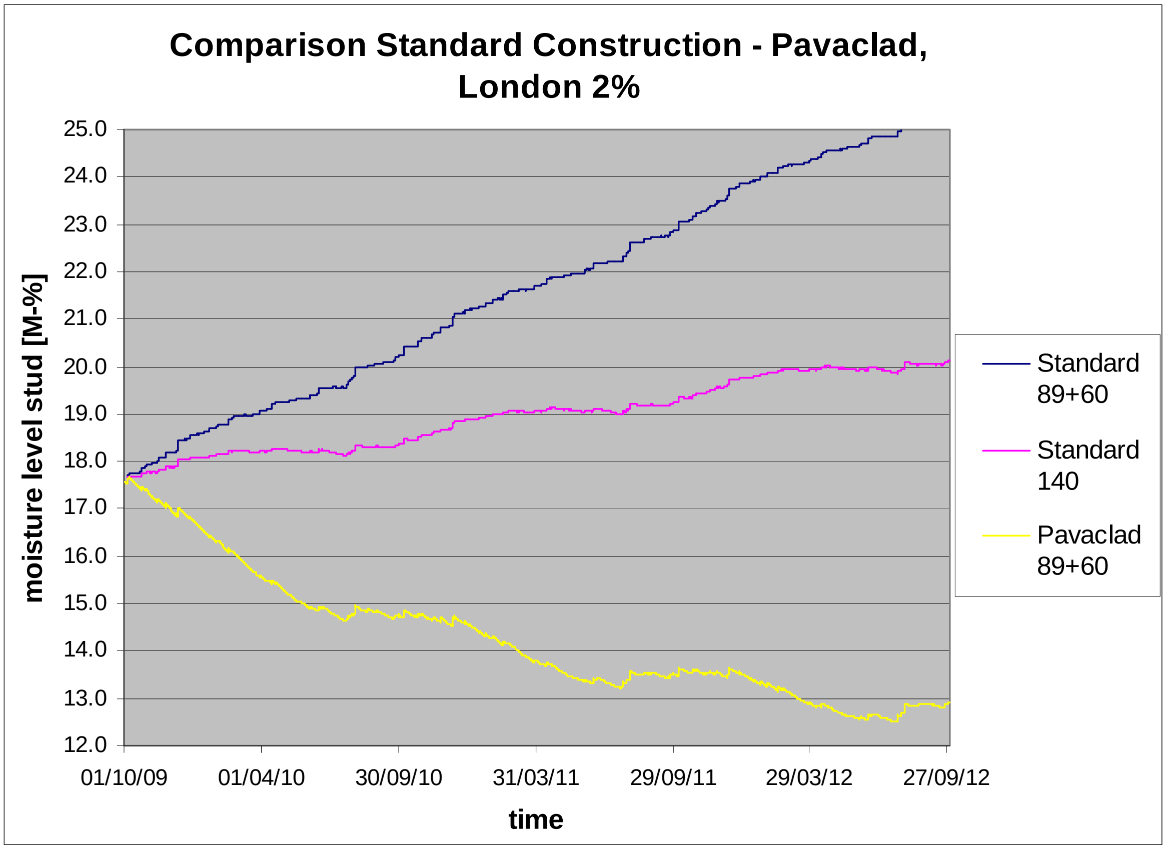
In the breathing wall, **Pavaclad** (inside to out)
12.5mm Plasterboard and skim
9mm OSB
89mm Timber studs full filled with Pavaflex insulation
100mm Pavatherm Plus (Woodfibre)
40mm vented cavity
20mm of timber cladding

The constructions have approximately the same U values.

All constructions are fine in terms of moisture if there is no moisture penetration of the structure. But what happens if moisture does get into the structure? The Fraunhofer Institute models building faults by inserting moisture into the build up, usually to a maximum of 1% of the total rain fall per m2 of a particular location (in the UK the BBA have asked our company to also model with 2% because they rightly assert that building skills are not so good as in Germany).

Below you can see that what happens if you put 1% of rainfall into the standard constructions and the Pavaclad breathable construction in London (Mild Exposure) and Swansea (Very Severe Exposure). This equates to 0.6ltrs per m2 per year in London, and 1.5ltrs per m2 per year in Swansea. We have looked at what happens to the moisture level in the stud (spread evenly over the whole stud as per Fraunhofer recommendation).




Comparison Standard Construction - Pavaclad, London 2%
moisture level stud [M-%]
25.0
24.0
23.0
22.0
21.0
20.0
19.0
18.0
17.0
16.0
15.0
14.0
13.0
12.0
01/10/09
01/04/10
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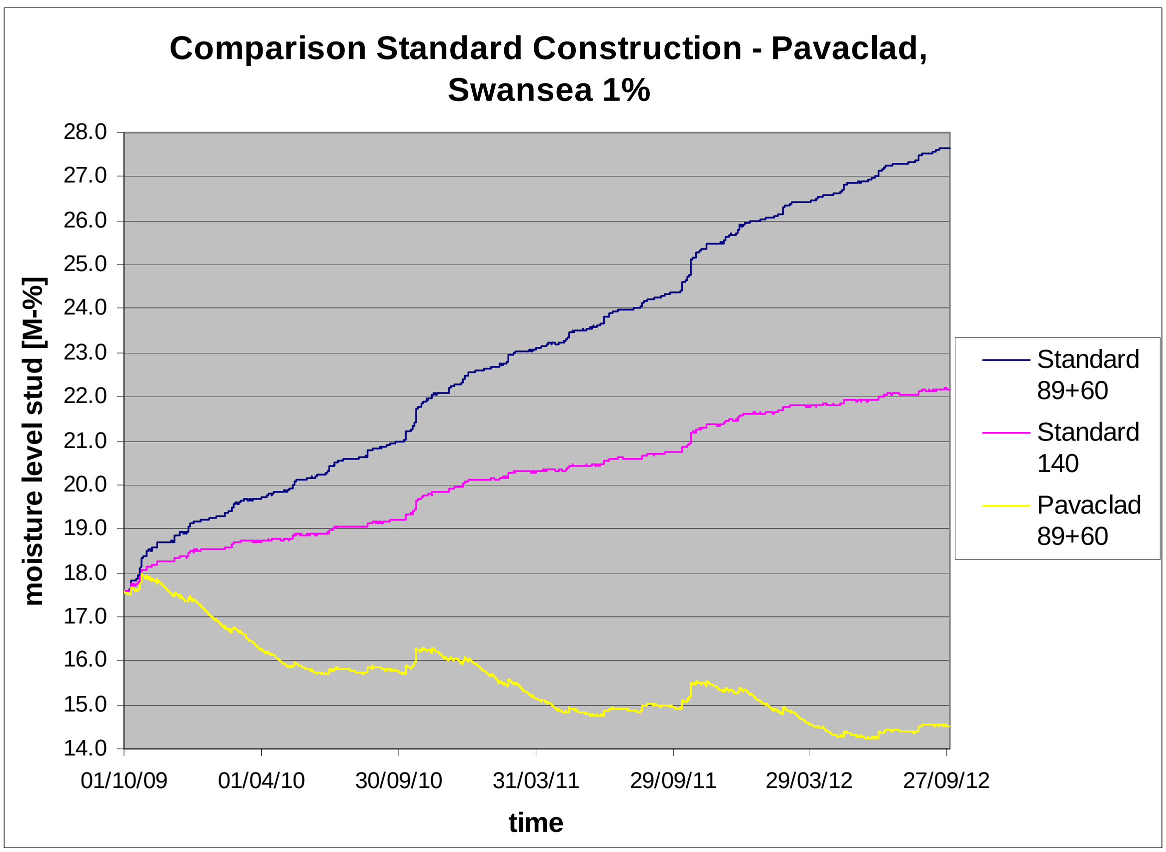
time
Standard 89+60
Standard 140
Pavaclad 89+60


Comparison Standard Construction - Pavaclad, Swansea 1%
moisture level stud [M-%]
28.0
27.0
26.0
25.0
24.0
23.0
22.0
21.0
20.0
19.0
18.0
17.0
16.0
15.0
14.0
01/10/09
01/04/10
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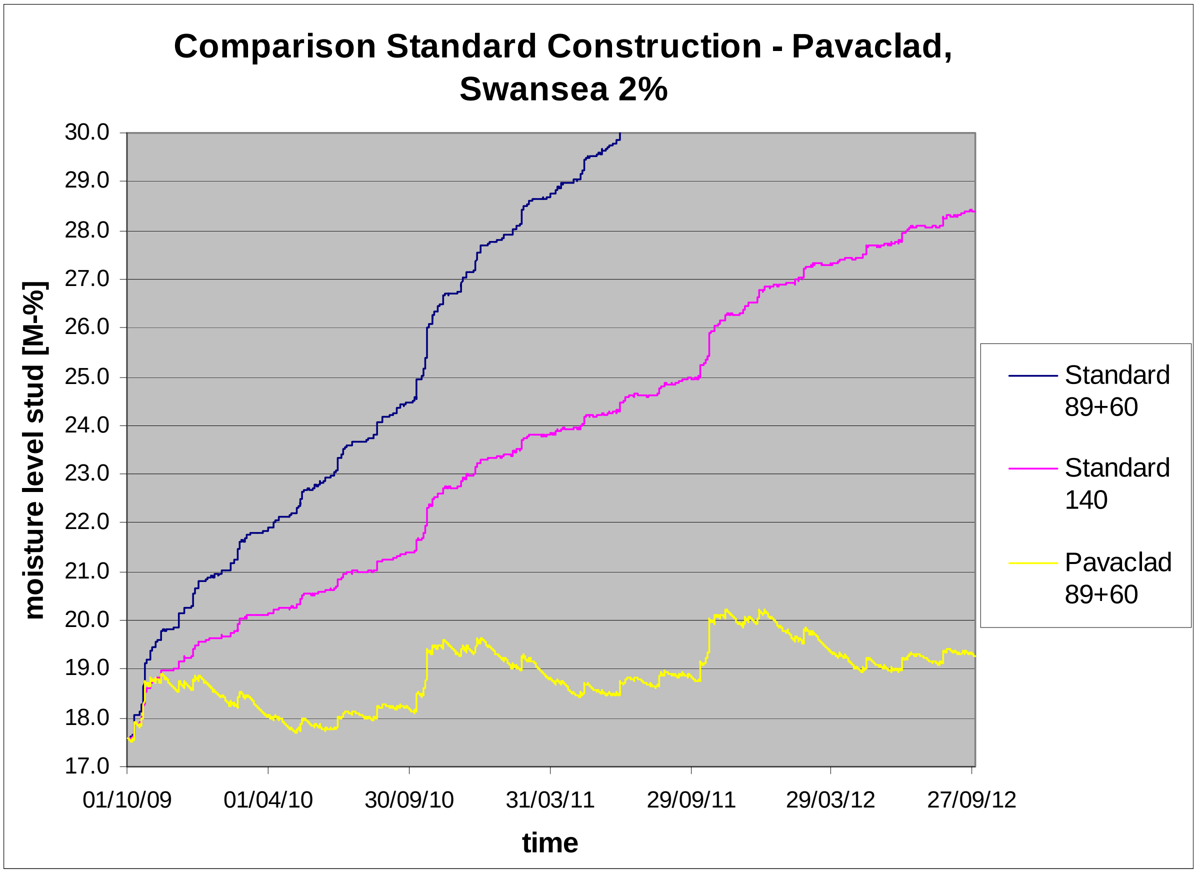
time
Standard 89+60
Standard 140
Pavaclad 89+60



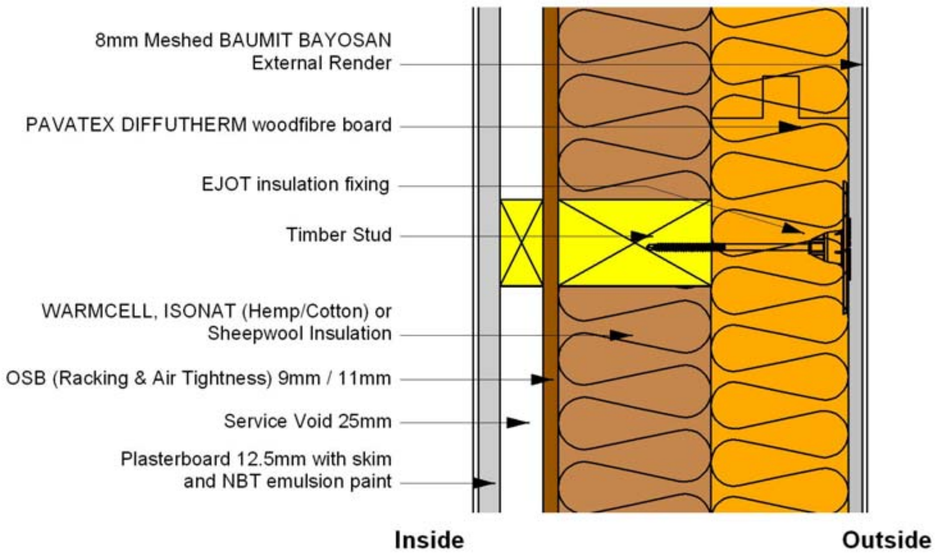

In the standard construction (140mm stud full fill mineralwool) in London, the moisture level remains constant over the 3 years with 1% ingress and rises slightly with 2% ingress. However with the standard construction with 60mm PU insulation (without foil) externally the moisture rises over the 3 years modelled and will reach tipping point after only 2 years. It would be worse if the insulation also had foil on it.

In Swansea the situation is that both standard constructions accumulate moisture within the stud, with the PU construction being far worse. With only 1% moisture ingress the tipping point for biological decay is reached within 9 months in the PU construction and after 15 months with the 140mm construction with external insulation. When 2% water ingress is calculated the situation is far worse in both situations.

In the Pavaclad breathing wall constructions however water content is continually and safely reduced in all situations except 2% ingress in Swansea, where the level rises very slightly.

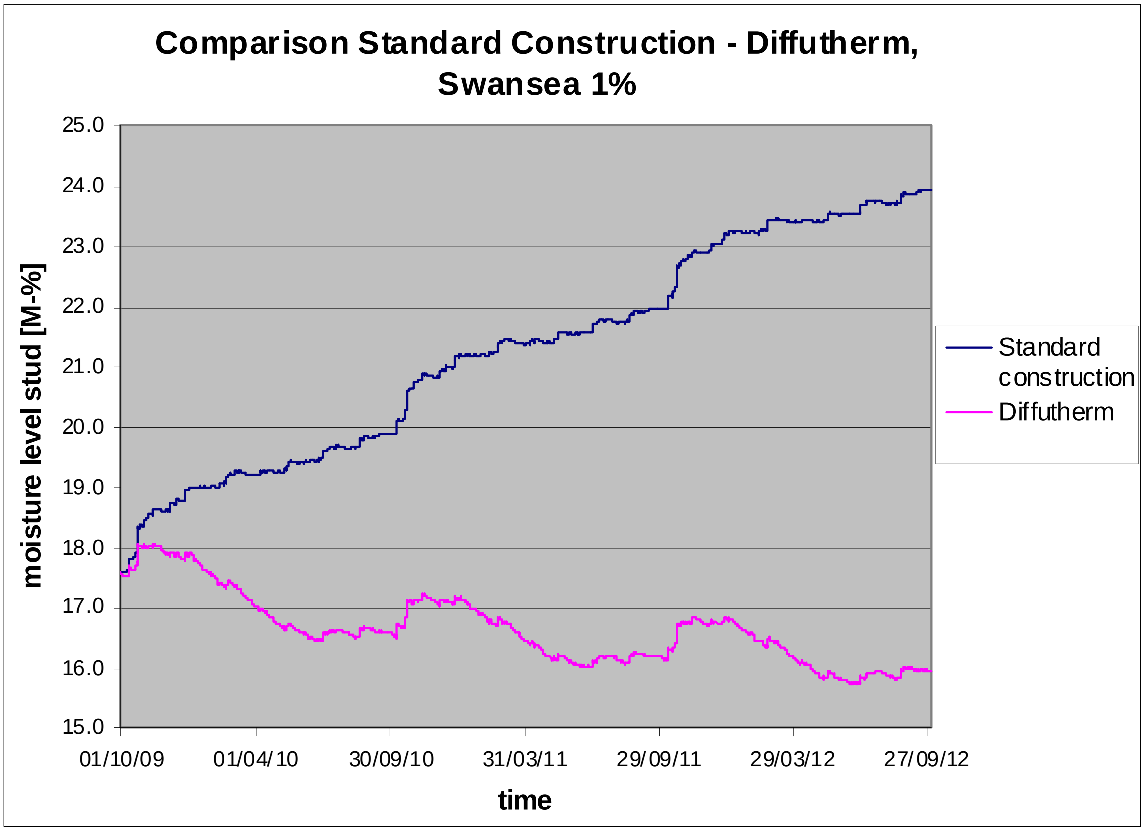
Why is this? It is basically because of the vapour permeability of the woodfibre layer. However it is also helped by the hygroscopicity of the woodfibre which draws moisture out of the construction rapidly due to the high equilibrium moisture content (EMC) and rapid take up of moisture by woodfibre. The capillary open and hygroscopic qualities of the flexible woodfibre or other natural insulation would also draw moisture away from the timber studs but this added benefit has not been taken into account in these calculations.

These qualities not only protect fabric, but also open up great possibilities of safe, simple to build and cost effective constructions. In particular the use of unvented rendered timber frame constructions where the OSB is on the inside and the insulation is directly fixed to the outside and rendered without a cavity, is safe with woodfibre boards but not with Expanded Polystyrene. Below is a drawing of the NBT Diffutherm system to show how this works.




This system has great cost advantages (particularly when compared to alternative to timber frame cavity and rendered blockwork), is much thinner than vented construction, and is easier to build correctly and robustly. It also has excellent fire and acoustic performance.

The safeness of the system utilising Diffutherm boards is due to the combination of the breathability qualities (vapour permeability, hygroscopicity and capillarity) of the woodfibre and the positioning of the OSB board on the inside of the structure. The contrast between the use of Woodfibre with render and Expanded Polystyrene with a similar render on the outside of the studwork is clearly shown in the chart below. The comparison is with 1% water ingress in Swansea:



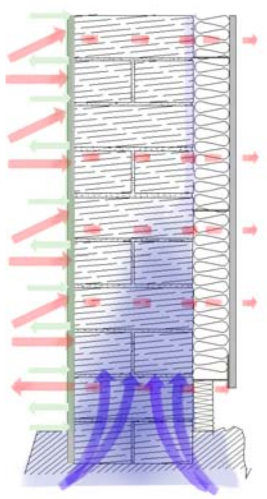

As can be seen, the woodfibre (Diffutherm) system continues to dry out even with 1% water ingress whereas the same system with EPS replacing the woodfibre reaches the decay tipping point after one year. For this reason BBA are now completing the NBT Diffutherm system approval, but will not consider synthetic insulations for this application.

There has been a great deal of concern about unvented rendered timber frame because of major failures in Canada, the US and New Zealand. However in all these cases, not only were there major design faults (balconies tipping water into the frame for example!), but also the constructions typically had OSB on the outside, encased in polythene, with a mesh and render applied straight onto this. No wonder there were problems! This does not mean however that there are problems with properly designed fully breathable constructions. Pavatex Diffutherm constructions have been installed since the early 1990s and are now sold at over 1 million m2 per year in Europe. There has never been a single claim against the system for moisture related problems.

Woodfibre (NBT Pavatex Diffutherm) boards being applied to a bungalow for disabled in Swansea. As can be seen the boards are applied directly to the studs. They are then rendered with a proprietory breathable render system, as in the next image.

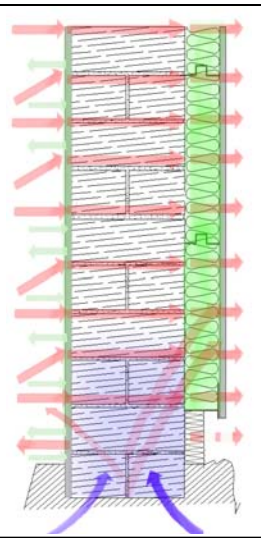
**Insulated Masonry Constructions and breathability:**

We have also modelled what happens in building faults with External Wall Insulation onto masonry. With most constructions there is no problem until we reach even higher rainfall %, such as 5% in London or 3% in Swansea. Here again in both cases Woodfibre insulation does not accumulate moisture the brickwork behind the insulation whereas PU or EPS based insulation system do accumulate moisture. High moisture levels in masonry work leads to a decline in the overall thermal performance of the construction in comparison with the same construction with dry masonry (this has been observed in several studies on the continent often to a factor of 30% lower resistance) and also to mould formation and bacterial activity. In particular there is threat in old buildings where floor joists and other timber are within the external masonry that these will get damp and start to decay. There are also real issues where insulation is applied to masonry with residual moisture, due to poor construction planning, or lack of damp courses. Below are diagrammatic pictures of the external insulation of a typical 9" brick wall with either EPS or woodfibre insulation (here Pavatex Diffutherm).



*Polystyrene EWI system onto Victorian wall*

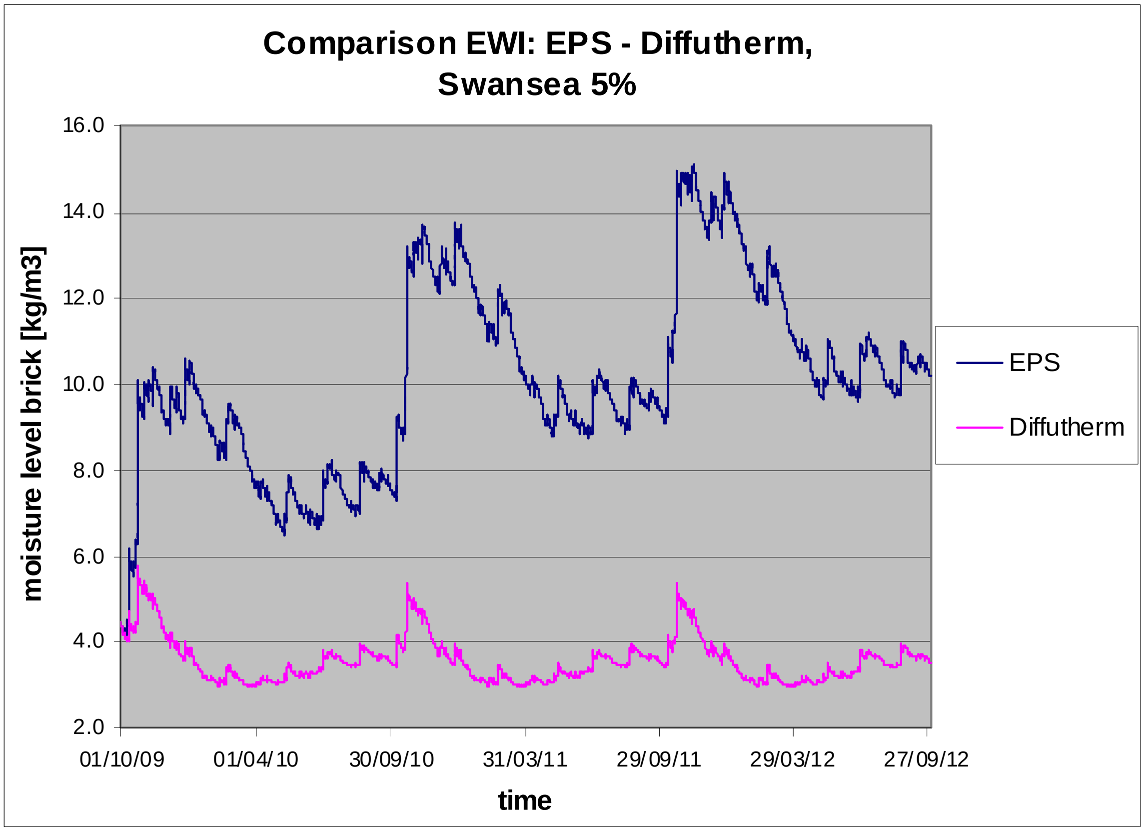
This system traps rising damp and inhibits vapour dispersion through the wall, thus making the wall damper and lowering its thermal resistance. Moulds may form particularly at the lower level of the wall, if there is no effective damp course. Furthermore if there is rain water penetration around openings this moisture will be trapped.



*Pavatex Woodfibre EWI system onto Victorian Wall*

This system allows rising damp to be dispersed and keeps the wall dry by the vapour open and hygroscopic external board and render. The wall remains dry even with severe rain penetration from outside.

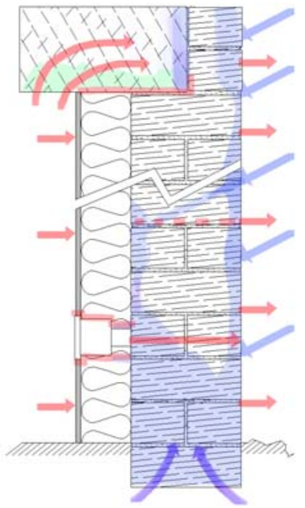
The question is, how bad are our building faults and how long do we expect EWI systems to last? What we can say is that woodfibre solutions are much safer in terms of building faults. Interestingly even at 5% water ingress in Swansea there is no problem for the wall with Diffutherm insulation on the outside, whereas with EPS the moisture levels are accumulating rapidly. This equates to 7.5litres of water per m2 per year.




**Internal insulation on masonry walls**

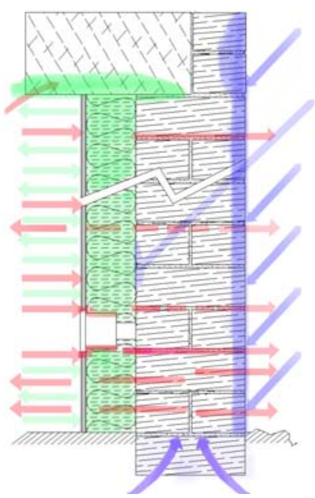
Finally the physical moisture qualities of natural fibres can be extremely helpful in internal insulation solutions. These are the most hazardous from a moisture point of view, in terms of the risks of poor design and poor application. Most standard non-breathable systems are modelled on a section of wall without any internal wall or floor junctions. However it is the wall and floor junctions which are the whole challenge of internal insulation, so we have to be certain that if we cannot ensure that moisture cannot penetrate through these junctions, there will be no real risk. In my opinion it is very difficult to eliminate this risk.

Below are some diagrammatic representations of the problem.



*Solid internal insulation with vapour impermeable barrier or insulation.*

Vapour ingress through breaks in the vapour barrier (ie at sockets) may form condensation on wall and make the wall damp. Rising damp and rainwater penetration will only be dispersed slowly to outside (as wall is now cold). Floor/ ceiling joists in wall will be particularly vulnerable. Timbers going into the wall will absorb moisture mainly from air leakage at the wall junction and will act as cold bridges leading to condensation at cold joist ends eventually leading to timber decay.

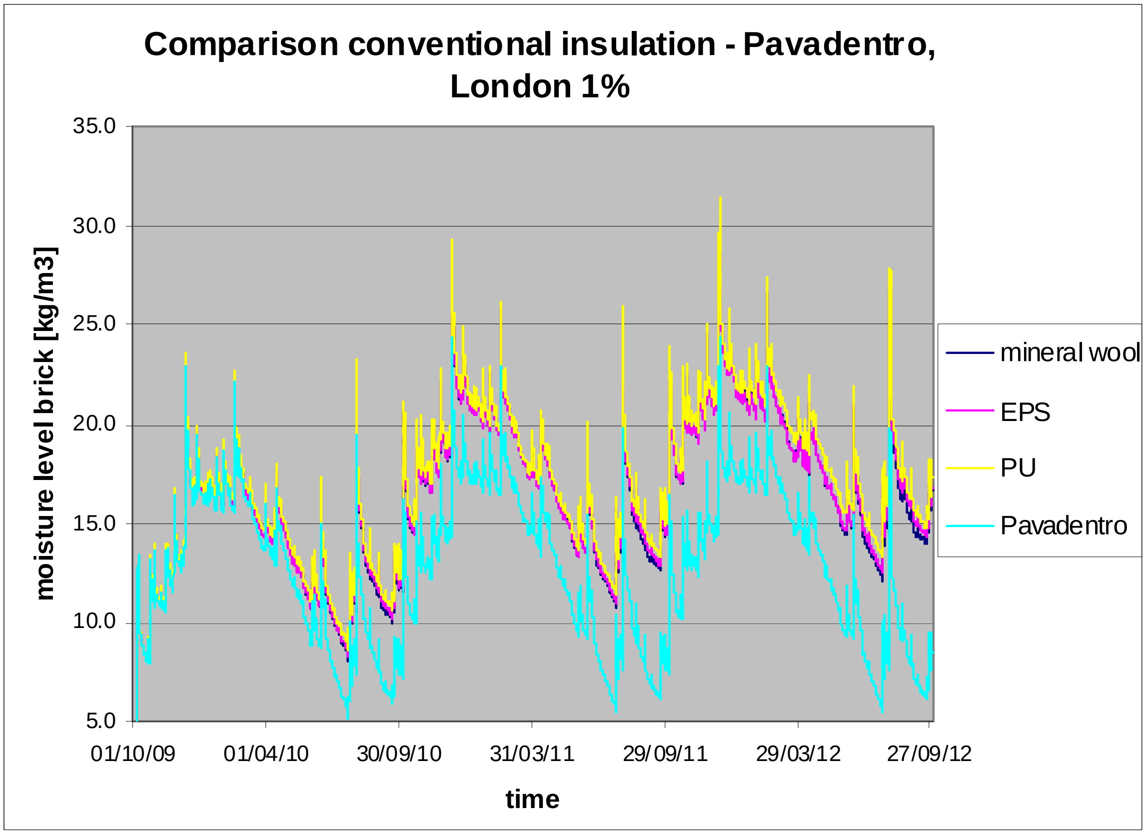


*Solid internal insulation with vapour open hygroscopic insulation.*

Vapour penetrations through gaps in the insulation (ie sockets) will be held hygroscopically and dispersed either inwards or through wall. Rising damp and rainwater penetration, as well as moisture in joist ends will be drawn hygroscopically and through capillary mechanisms into woodfibre and dispersed inwards or outwards through vapour open materials. The internal lining acts hygroscopically to buffer humidity internally thus reducing the vapour diffusion into joist ends and giving good internal air quality.

Below we see whether these diagrams are correct by comparing two situations of internal insulation of a 215mm solid brick wall: the first is again a conventional construction with vapour barrier, a conventional insulation (mineral wool, EPS, PU) which rely on the vapour barrier to prevent moisture getting into the wall and forming condensation, and the second is the Pavadentro system which works by utilising the capillary and hygroscopic qualities of the woodfibre (along with a breathable silicate layer to slow down vapour transmission) to provide a safe solution in situations of imperfect building design and practice. In reality it is almost impossible to provide a fully airtight and unbridged internal insulation layer unless all internal floors and walls are removed prior to internally insulating. So the problems of bad design and practice occur in most situations of internal insulation.

We have put 1% of water into the two different constructions as follows:




As can be clearly seen only the Pavadentro solution is safe and the others are not. In fact in all the models we made of water into the construction in London and Swansea, the amount in the Pavadentro constructions remained stable and able to dry out seasonally.

The refurbishment of buildings is extremely costly and to make any sense financially or environmentally has to work for decades. The difficulties of undertaking internal insulation to ensure that there is no airleakage of moisture into or trapped damp in the insulated walls means that in only breathable solutions are able to ensure long term health and performance.

**External walls and breathability:**

From the evidence above and also from many studies of the problems of non breathable materials in construction, particularly in refurbishment of older buildings, we can clearly say that breathability is an issue of utmost importance. We can also say that this is not only in relation to the health of the building fabric, but also in terms of the health of human occupants. Damp walls and timber frames even if treated, will lead to moulds in the structure. Mould spores are incredibly small and can penetrate even solid rock. So damp structures can lead to mould formation and to the contamination of indoor air, with the consequent risks to human health, which have been well documented. Eventually the dampness will cause structural failure as timber treatments do not last forever. To say that breathability in insulation or external wall construction is a red herring is therefore not only technically incorrect, but is highly irresponsible.

**Hygroscopic Buffering**

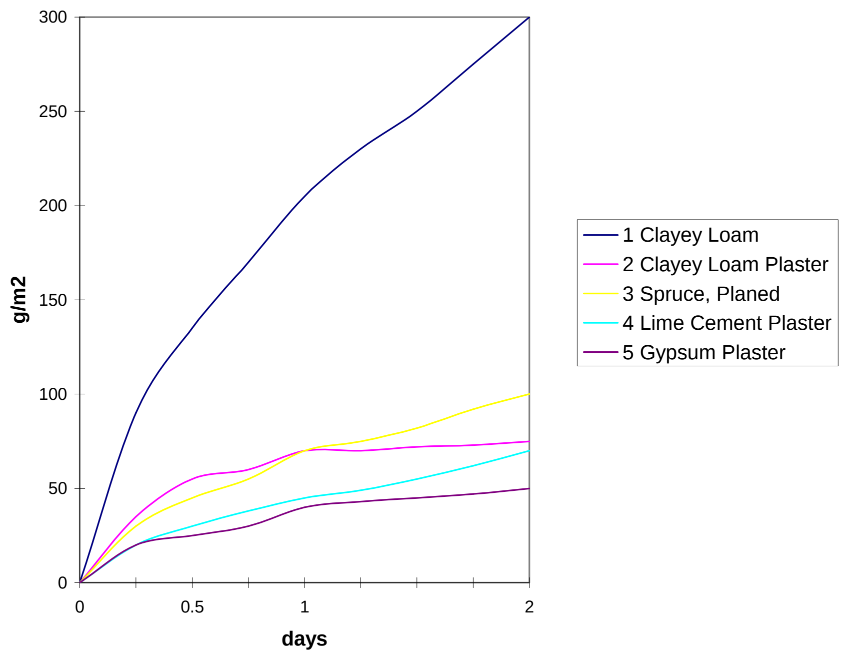
To confine "breathability" to external walls and the issue of trapped moisture due to poor construction or ongoing building faults, however, is to miss out whole aspects of breathability which in future may play a significant role in assisting to improve the health of buildings as well as allowing us to develop new low energy building solutions.

It has been known for a long while that hygroscopic materials can reduce levels of relative humidity in buildings and thereby create healthier indoor climates. This technique has been shown in museum and archive situations to be more effective in controlling RH than airconditioning or other mechanical means (see the work of Tim Padfield, for example at [www.natmus.dk/cons/tp/tp.htm](www.natmus.dk/cons/tp/tp.htm)). Hygroscopicity as stated above is the quality of a material to absorb and desorb moisture as relative humidity changes. Most materials do this to some degree. As humidity changes so does the Equilibrium Moisture Content of a material. This is usually measured as the amount of water per weight of material, and portrayed as a percentage. What is important, however, is not only what this percentage is, but also what the density of the material being used is, and the speed of adjustment to the EMC. Below is a table which shows some comparative figures for certain materials. There is also a comparison between unfired clay blocks and conventional plasters in relation to speed and quantity of uptake.

| Material | Density Kg/m3 | EMC at 50% RH (at 20º C) | EMC at 85% RH (at 20º C) | Hygroscopicity (increase in moisture/mass at 20º C from an RH of 50% to 85%) | Hygroscopic capacity Density x Increase Kg/m3 | Speed of hygroscopic take up |
|---|---|---|---|---|---|---|
| Cement render | 2000 | 0.5% | 2.5% | 2% | 40 | Slow |
| Lime render (hydraulic) | 1600 | 1.25 | 3% | 1.75% | 28 | Slow/medium? |
| Gypsum plaster | 850 | 0.4% | 1% | 0.6% | 5.1 | Medium |
| Concrete | 2000 | 0.5%? | 2.5%? | 2%? | 40? | Slow |
| Aerated concrete | 600 | 0.9% | 2.5% | 1.6% | 9.6 | Medium |
| Fired Clay Brick | 1700 | 0.1 | 0.2 | 0.1% | 1.7 | Medium |
| Unfired Clay Brick | 1700 | 4 | 7 | 3% | 52 | Very Fast |
| Spruce transverse | 600 | 9 | 18 | 9% | 54 | Slow |
| Spruce end grain | 600 | 9 | 18 | 9% | 54 | Fast |
| Plywood | 500 | 9 | 18 | 9% | 47 | Very Slow |
| Mineral wool insulation | 10 | 1.3 | 2.3 | 1% | 0.1 | Medium |
| All plastic insulations | 10 – 20 | 0 | 0 | 0% | 0 | N/A |
| Woodfibre board insulation | 200 | 8 | 17 | 9% | 18 | Fast |
| Cellulose insulation | 45 | 8 | 17 | 9% | 4 | Fast |

| | | | | | | |
|---|---|---|---|---|---|---|
| blown | | | | | | |
| Flax/ hemp/ sheepswool insulation | 25 | 8 | 17 | 9% | 2.25 | Fast |
| All paints | 0.1 – 0.3 | N/A | N/A | 0% | 0 | N/A |

**Comparison of speed of hygroscopic absorption 1**




The way that hygroscopic buffering works is, crudely, that if the Relative Humidity rises from 50% (which is a good healthy ambient RH) to 85% due to cooking, bathing, having a party, ventilation failure etc, then a highly hygroscopic material will quickly absorb extra moisture and thereby reduce the moisture in the whole room. Recent work done in humidity chambers in Holzkirchen (Svennberg et al; Journal of BUILDING PHYSICS, Vol. 30, No. 3—January 2007) shows that the difference between a room covered with a non hygroscopic material (aluminium in this case) and a room with vapour open standard hygroscopic plasters under similar humidity and air permeability conditions is immense. In the non hygroscopic room the RH levels reached almost 100% at times whereas in the other room the RH fluctuated between 40 and 60% (the safe zone). In the standard room twice as much water was contained by the hygroscopic materials as was dispersed through air leakage.

Research done on lived in unfired clay (earth) buildings in Germany shows incredibly stable RH levels only varying from 50% by plus of minus 5% over 10 years periods even in modern living conditions. There are also many case studies of the use of unfired clay in bathrooms to prevent condensation on walls and fittings. We ourselves have attempted to measure the hygroscopic qualities of unfired clay blocks in a laboratory humidity chamber, but were unable to do so due to the fact that we could not actually raise the RH to 85% due to the hygroscopic mechanism of the clay, which rapidly and consistently drew moisture out of the air!

It is natural materials and in particular natural fibres and unfired clay which have the best hygroscopic qualities of all construction materials. There is still much work to be done to maximise their value in common building situations. However it is clear from material testing and from case study examination that they could play a very significant role in the future both in refurbishment and new buildings, particularly as buildings become more airtight. In fact hygroscopicity only becomes important for internal air quality in airtight buildings, as in leaky buildings the outside air Relative Humidity will over come any effect of internal control. Some of the exciting possibilities relate to passive humidity controlled ventilation systems and some to situations where no retrofit ventilation system is possible. We cannot always rely on mechanical ventilation systems to sort out all our problems as these need correct installation and maintenance over the life of a building, and do not always prevent micro climates and low level accumulation of moisture in buildings even in good designs.

So to say that breathable materials have no effect in reducing internal condensation moulds and dustmites is wrong. They have an absolutely vital role to play and are playing this already through the many natural fibre furnishings and fittings in buildings. In future, with better research and monitoring, they may become an essential part of a robust solution for good indoor air quality in both new and refurbished buildings. As the recent academic review of hygroscopic buffering concluded: "field measurements, in combination with simulations, proved that moisture buffering is an indispensable element in the description of the water vapor balance in the indoor air" (Svennberg et al; Journal of BUILDING PHYSICS, Vol. 30, No. 3—January 2007)

**Conclusion:**

We have only scratched the surface of what is a vast and complex subject. However I hope that I have sufficiently demonstrated that not only is it misleading to say that breathability in regard to insulation is a red herring, but it is also irresponsible. It is irresponsible not only in regard to fabric health and human health, but also in regard to the positive possibilities of producing safer, healthier and better performing buildings.

Neil May, 6 November 2009

References:

Breathability: the Key to Building Performance by Neil May on www.natural-building.co.uk

Breathability Matters (longer version) by Neil May on www.natural-building.co.uk

Works by Tim Padfield on www.natmus.dk/cons/tp/tp.htm

Publications by Society for the Protection of Ancient Buildings, such as The Control of Damp in Old Buildings and Timber Decay in Buildings. See www.spab.org.uk