The risks of retrofit

In the first article in this series we saw how improving the energy efficiency of homes, especially those where people live in fuel poverty, can improve the lives and health of the occupants. Part two examined the benefits of deep retrofit, and found it can enable much more robust energy savings, and transform the comfort and appearance of a home. Kate de-Selincourt continues her report and, in this issue, considers the risks involved with retrofit...

It isn't all plain sailing. While the majority of retrofits deliver something between a bit more comfort and a lot more comfort, plus significant energy savings, sometimes things can go wrong.

The underperformance of shallow and/or inept retrofit was touched on in earlier articles, and is certainly a financial hazard – and also makes a subsequent 'proper job' less likely and less affordable – locking in the poor performance. This article, however, is looking at practical hazards that can sometimes arise after retrofit – endangering the health of the building, the occupants, or both.

In the most extreme (and very rare) cases, faulty retrofit has led to the demolition of whole buildings. Less unusual and drastic is for retrofit measures to be reversed, or for additional remediation works to be needed. Damp, condensation and mould are the most usual problems, and many retrofits affected by moisture problems will be underperforming thermally as well. The issues are often interlinked, and a good installation can hopefully avoid both at once.

The 'headline' causes of retrofit problems tend to include:

- Poor (or no) design.
- Unsuitable materials.
- Poor workmanship, design or guidance ignored.

These issues tend to be exacerbated by the prevailing advice, evaluation and funding systems, which are generally based on individual measures, and incentivised on a crude '£/tonne of carbon' basis, derived from a simple RdSAP assumption about the measure in the abstract, rather than in the context of the particular building.

In this article we will look in most detail at how these issues affect one main retrofit measure – insulation of solid walls – as this is the subject of much current investigation. However, many of the same issues about the need for empirical science, the importance of holistic design, attention to detail, and the need to prioritise the building and its occupants, apply to all aspects of retrofit.

Internal wall insulation

Internal insulation of solid walls is pretty widely understood as 'tricky', and guidance is in place, designed to avert the risk of interstitial condensation (where moisture from the interior finds its way to the cold building fabric behind the insulation, where it may condense, and potentially lead to mould or rot).

However, well-intentioned as this advice may be, it is based on quite a limited set of assumptions. This, from an internal wall insulation manufacturer's factsheet, is typical: 'Except in unusual circumstances, such as rising damp or a leaking pipe, the moisture in a wall comes from the inside not the outside.'[1]

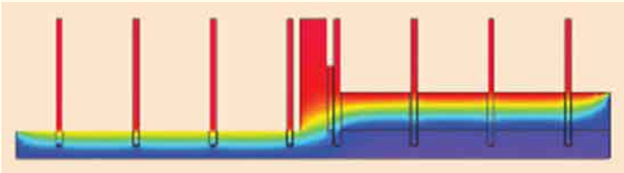
Depending on the construction, location and orientation of the building, however, more moisture may come in to the house from outside than is generated by the occupants. Wind driven rain can affect the entire thickness of solid walls, and this process can, perhaps surprisingly, be exacerbated by sunshine. The mechanism of 'reverse condensation', or solar driven condensation was explained by Matt Smith of NBT at the Retrofit Live event in April 2015:[2]

1. Rain falls on a masonry wall and soaks in to the surface.
2. Sun shines on the wall making the outside of the masonry warm (may be 30-40 degrees), evaporating the water and leading to an increase in vapour pressure (ie, an increased concentration of gaseous water).
3. Some water vapour will immediately return to the atmosphere – the outside of the wall is being dried by the sun. Some water vapour, however, will go the other way and move through the masonry, either through cracks and joints, or even through the solid fabric, depending on how the wall is made. Almost all building materials (even concrete!) are vapour permeable to a degree – and/or, will have holes somewhere.
4. Water vapour reaches the cooler interior of the masonry, away from the sun, where it may condense.
5. The water has to evaporate if the masonry is to dry again; it can go back the way it came (though this may be slow as the sun doesn't shine on the inside of walls). If the internal construction is vapour open, the water can also evaporate into the interior of the building to be removed by the ventilation.

If there is an impermeable vapour control layer (VCL),

Behind the insulation – a colder wall

The diagram demonstrates the modelled temperatures during the heating season of two adjacent external walls, at the intermediate floor level, with, as is usual, the floor joists buried half in the wall. The segment on the left is uninsulated, the one on the right, insulated. The joists in the insulated side have reached a lower temperature than those on the uninsulated side, including where they pass though the insulation layer. Taping a VCL to the joists is sometimes suggested to protect



this cool structure from interstitial condensation – but might it worsen the risk from moisture from outside condensing there and damaging the timber? (See discussion in text of main article). One option that is sometimes deployed is to take the joists out of the masonry and suspend them from joist hangers – quite a big job though! On the Georgian retrofit described on this page, a combination of hygroscopic insulation, injected boron gel, and monitoring, was used as an alternative.

the water vapour from the outside will hit the back of the VCL, where it may well condense – and also on any structural timbers behind the VCL. While some of the vapour will go back the way it came, the VCL will hinder the process of drying out to the interior, Matt Smith warns, and may lead to worse problems with moisture than the VCL has prevented.

Using WUFI, Matt Smith modelled this phenomenon for a variety of locations and wall orientations. He pointed out that the current guidance is based on Scottish measurements where insolation is relatively low (even in summer); "We modelled for other climates, for example Cornwall and London - London has a lot of sun, Cornwall also has strong sunshine and, of course, a lot of driven rain, including on south elevations." So the problem may well be greater than has been generally understood.

To predict this phenomenon with any confidence you need to know the characteristics of the wall itself, and how it behaves in relation to liquid and gaseous water. In fact masonry is very poorly characterised – probably hardly surprising as there are a lot of different wall types, and it isn't just the brick or stone, it is the mortar – and even the bond – which affects both the hygroscopic, and also the thermal behaviour of masonry. It is possible to test some of the moisture characteristics of a wall in situ, if this is likely to be a critical issue in a particular retrofit.

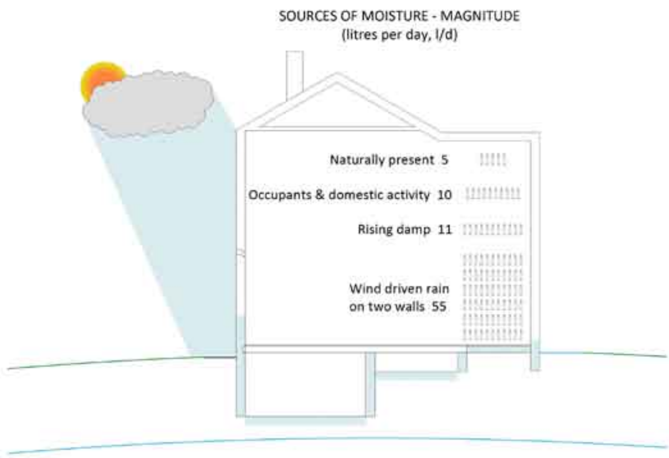
The volumes of water that pass through masonry into the indoors are not insignificant. The team at the AECB, who are creating the new CarbonLite Retrofit course, have estimated that the moisture passing through unprotected masonry may exceed the moisture generated by occupants up to tenfold (see diagram bottom of page). Joseph Little agrees – "The greatest moisture load (in the wall) is often not from the room." This, incidentally, is the reason cavity construction and dpcs began to appear in the 19th century in Britain – to keep some of this moisture out.

This is not just a theoretical risk – net movement of moisture from masonry into the interior has been demonstrated by careful measurements of the moisture in walls. In his talk to Retrofit Live,[3] Harry Paticas of Arboreal Architecture, shared the results of monitoring in the brick walls of a listed Georgian house for which he designed the comprehensive refurbishment. Measures included repointing, airtightness, mechanical extract ventilation, and internal insulation with wood fibre insulation and a moisture-variable vapour check membrane designed to handle interstitial condensation and transfer it back to the surface.

Monitors were installed at a number of points through the thickness of the walls during the refurbishment, and the data (over almost two years) has been analysed by Tim Martel of the AECB CarbonLite team. The analysis shows that moisture moves two ways through the wall, with the dominant direction at the inside being drying into the room, especially in summer, but with some moisture going back from the room into the masonry – then through and out into the outside air – during the winter months.

While the details will vary with every wall construction (and every location and every year) the example here clearly shows moisture passing in to the building from outside, and not just out from in.

Potential moisture loads via rising/ penetrating damp (example based on 9" solid brick wall, no dpc,exposed to wind-driven rain). Courtesy AECB CarbonLite Retrofit.



Keeping water out of the masonry in the first place is an attractive option and various strategies are available.

Well-installed external insulation should certainly keep out the rain (though see below for considerations about rain-proof detailing, and also the possible consequences of applying to already-wet masonry).

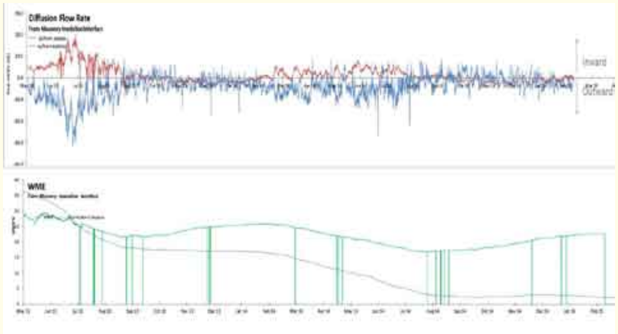
Where IWI is being contemplated, this is often because the building owners or the local authority have rejected EWI on aesthetic/conservation grounds. But less conspicuous strategies for keeping masonry dry are also possible. The house above was repointed with a more moisture-repelling, but vapour-open, mix than the old mortar -- this had been in very poor condition and was tracking moisture into the brickwork. However, as the building was listed, that was the extent of measures allowed on the outside.

Architect, Andy Simmonds of Simmonds Mills Architects, has experience of retrofitting a solid walled house which, while ineligible for EWI, has nonetheless been allowed to be treated with 'brick cream', a hydrophobic but vapour open compound which dries see-through. To investigate the effect of the brick cream, half the west facing wall was treated with cream the other half not. Vapour permeable IWI and an intelligent (variable vapour resistant) membrane has been installed, and a dpc was injected.

Moisture levels in the masonry treated with cream fell more rapidly than in the untreated areas, and also faster than the previous example, probably as less 'new' water has been coming in. Drying was once again to both inside and outside but the pattern was very different, with some moisture still passing from the interior to outside but a lot less coming in the other way.

Diffusion of moisture through the inside and outside face of a brick wall

In the top part of the figure, the red line represents vapour magnitude and direction on the inside of the wall, here it is mostly above the axis, showing vapour is usually moving inwards. The blue line indicates moisture movement at the outside of the wall, and this line is mostly below the axis, which means vapour is being lost to the outside. So, essentially in summer the wall is drying out on both sides (a great deal at the start). There is some minor reversal in winter, when a little moisture moves into the wall from the inside, and leaves from the outside. The net direction of moisture movement on the inner surface however is overwhelmingly in from the wall to the room.



If you look at the net effect of both these lines (the blue line) it shows that it is always going down, or at worst level, which means overall, vapour is only being lost from the masonry, ie the newly refurbished building is drying out.

Courtesy of Arboreal Architects and AECB

Standards, which standards?

Neil May of the Sustainable Traditional Building Alliance and Joseph Little warn that the standards, the warranties and the rules for funding measures, where moist masonry is an important consideration, are not always consistent with recent research like that seen above. For example, BS 5250, as referred to in Part C of the Building Regulations (Site preparation and resistance to contaminants and moisture) and in many insulation system warranties, takes no account of driving rain; it focuses on interstitial condensation in the heating season and is about vapour. As Neil May explained at Retrofit Live: "Using 5250 leads to recommendation of vapour barrier, yet if you model according to EN 15026, which uses different methodology taking into account orientation and driving rain,[4] you would get the opposite advice."

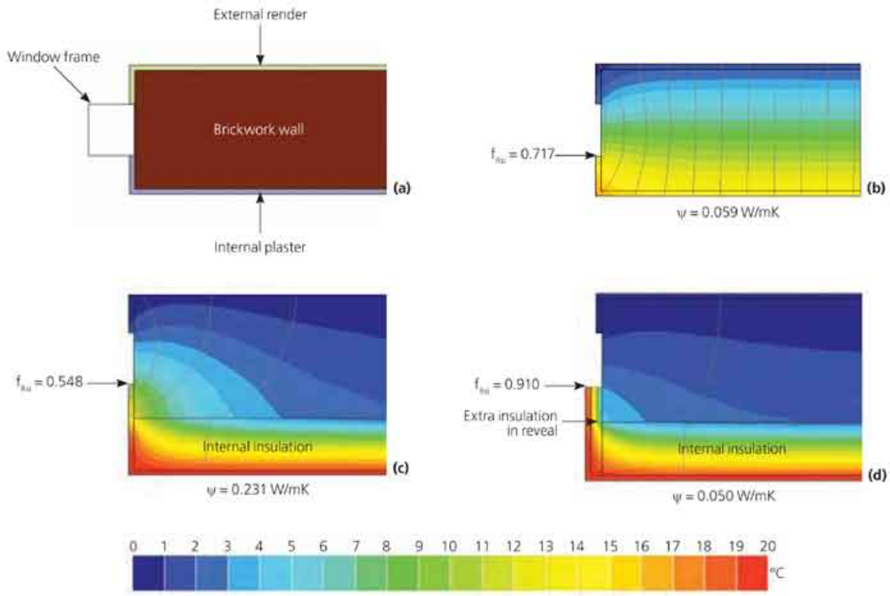
Knowing that the official advice may be inadequate is obviously worrying for anyone intending to install internal wall insulation, but fortunately this area is subject to active research, and more importantly, the researchers are willing to share their experience. Some new guidance is also due to be issued by DECC, possibly later this year.[5] There are even opportunities for practitioners to monitor their own installations (for example via the AECB arrangements for the purchase of moisture monitors) – both to check the walls are performing as intended, and also to add to the sum of monitored experience.[6]

Thermal bridging

With internal insulation, thought also needs to be given to the risks of thermal bridging. In an internal wall insulation installation, thermal bridging can lead to internal surface temperatures lower than on the uninsulated wall, increasing the risk of condensation.

The 'cold walls' (see boxout above) suggested that joist ends require detailed attention when carrying out IWI. Another fiddly job is insulating the reveals -– especially as most standard thicknesses of internal insulation simply won't fit.

As Neil May points out, the (necessarily thinner) insulation on the reveals does not need to be of a super-high performance material to be useful. A reduction in surface condensation risk, and greatly improved thermal



Reducing thermal bridging at junctions when designing and installing solid wall insulation. The thermographic simulations here demonstrate what happens if this job is skimped, however. Image (b) shows the pre-insulation base case for a theoretical solid wall, with a temperature factor of 0.7 at the window/reveal junction. After IWI is applied but with the reveal left uninsulated (c) a colder surface is shown to the room (temperature factor 0.55) – in (d) this is remedied by adding a thin layer of insulation to the reveal.

Caroline Weeks, Tim Ward and Colin King, BRE, 2013

performance can be achieved even with 20mm of normal insulation. May and colleagues at the Sustainable Traditional Building Alliance have calculated that adding 20mm insulation to the reveals might give the same improvement in thermal performance as doubling the thickness on the walls.[7]

Modelling the behaviour of heat is possibly more straightforward than modelling moisture; though as with moisture movement, the thermal behaviour assumptions normally used in modelling, are pretty simplified. BRE Wales has embarked on a major fabric characterisation exercise looking at the thermal performance of all kinds of solid wall constructions, so more guidance may be available in the future.

External wall insulation

External wall insulation poses fewer problems, at least in theory, than does IWI. As Joseph Little of the Building Life consultancy explains: "it makes the wall warmer and leaves its inner (plastered) surface unclad [so] gives the masonry the best chance to dry out."

However, damp and mould problems have been observed in some EWI installations, as Colin King of BRE Wales reports. King has visited numerous EWI installations, mainly carried out under CESP and ECO funding in low income neighbourhoods – and he has not been impressed by what he has seen. Problems for some occupants are apparent: " I have seen condensation mould and decay already in a number of instances."

Three big issues that have stood out to King are: large areas of thermal bridging (eg when the entire top or bottom of a wall is left uninsulated, or a whole window bay); poor detailing or installation that could allow rainwater to track behind insulation, and failure to repair fabric and/or rainwater goods before installation of EWI, that could also allow rainwater into the walls behind the insulation.

"I've seen 2000-odd EWI installations, and probably 20 of them had insulated the reveals and the floor slab. So nearly all of them have massive cold bridging, and they are just waiting for problems." Often the top of EWI is not sheltered by the house eaves, but is instead capped off with a trim sealed to the wall only with a line of mastic. Replacement windowsills may be missing a drip; crude unfinished cut-outs may be left for rainwater goods, service penetrations – or even in one notable installation – a lamp post!

One customer who had EWI fitted privately recounted his experience in the CORE Fellowship submission to the Green Construction Board Solid Wall Insulation consultation earlier this year. He reported that the contractor insisted on stopping short of the ground, the eaves and above any roof-wall junctions; his assessment was that these thermal bridges cost 40% of the suggested performance. On top of this, "damp appeared in various locations some months afterwards, eventually traced to rainwater running off adjoining tiled area where they had cut short a gutter to install the EWI."

The installers did not have a good strategy for dealing with this service entry, and there is a very large thermal bridge at the porch.

Courtesy of NDM Heath Ltd

If water is tracking into masonry and it is wetter than before, but uninsulated owing to large thermal bridges, the worse U-value of wet masonry may make internal surface temperatures lower than they were before. Or the moisture may simply be soaking right through - in which case a warm wet wall could grow mould even faster than a cold wet one anyway.

Finally, as with a range of energy retrofit measures, the fabric infiltration rate may have been reduced, intentionally or unintentionally, and this may, in some cases, be exposing the ineffectiveness of the ventilation (be it trickle vents, extract fans or simply window opening by occupants). Once again, this could lead to increased humidity indoors and therefore increased condensation and mould growth, (see the paragraphs on draughts and ventilation next page).

The way so many installations have been financed is likely to be a large factor in these problems, many believe. Architect, Nick Heath, was commissioned by English Heritage to evaluate three large-scale EWI programmes in traditional terraced housing in the north of England – many of the same installations visited by King. As he explains: “The way the jobs are funded and procured makes it almost impossible to do EWI properly; the many fine words of guidance may as well not be there. There is no time to deal with the fancy bits on the building, so you see massive thermal bridging – the sole measure of its success is numbers completed by the deadline . And there is never enough money for ventilation.”

The choice of contractor is generally dictated by the lowest price; referring to the inadequacy of the subsidies, Nick Heath pointed out that; “to do EWI properly may cost more like £15,000, not £5,000”. Quality control is limited to say the least: PAS 2030 permits installers to certify their own workmanship: “I have a bee in my bonnet about self-certification,” BRE's King says, “No-one is going to fill in their own self-cert form saying they mucked up the job.”

Although it is not well studied, one plausible cause of damp problems in these homes was that the walls were already damp when EWI was installed, Nick Heath suggested. A complete absence of finance for 'pre-remediation' in CESP and ECO budgets, to make the underlying fabric sound and dry, will not have helped, neither will the common situation of only having access to funding if the works can be completed in a really short timetable (often just a few months), making it more or less impossible even to survey the properties, never mind to put in place necessary repairs.

Similarly, 'carbon' oriented funding, though often (as with CESP and ECO) targeted towards people in fuel poverty (so therefore, unlikely to lead to major carbon savings) tends to be scored and reimbursed purely on a '£/theoretical tonne' basis. Once again, measures that could improve the lives of the occupants just as much, such as gutter repairs and upgraded ventilation, are excluded.

Even the apparently tried and tested insulation of cavity walls is not foolproof. In fact a Cavity Wall Insulation Victims Alliance has been established, to campaign for help for people whose CWI has gone wrong.

The worst problems appear to have been in the wetter west of the UK, in areas which may not have been suitable for CWI. This may have been the problem in some social housing in South Wales, where Newport City Homes are reported as having investigated damp reports by residents, and having found the cause to be cavity wall failure; “To remedy these issues we took the decision to remove all cavity fill.”[8]

Location, location

Driving rain is liable to make an uninsulated house damper and, therefore, colder. Unfortunately it also makes any insulation a riskier proposition.

Longstanding government advice in Part C states that; “When the cavity of an existing house is being filled, special attention should be given to the condition of the external leaf of the wall, eg its state of repair and type of pointing... The suitability of a wall for installing insulation into the cavity should be determined either with reference to the map [of exposure to wind and rain] and the associated table of following the calculation or assessment procedure in current British or CEN standards."

As a note on the Kingspan website put it: “Cavity wall insulation may not be suitable in properties which are exposed to severe risk from the amount of wind driven rain. Basically, in this situation, any damp or rain that penetrates the outer layer of bricks may be carried across the cavity by the insulation, through to the inner layer of bricks/blocks, and appearing as damp on the inner wall.”[9] Clearly, this advice has not always been heeded – as the RH map (green) published by the Cavity Insulation Guarantee Agency indicates.

As with cavity wall insulation, so with internal wall insulation – the higher the exposure, the more careful the design and modelling need to be, and the stronger is the case for protecting the masonry as well, if possible (though this cannot be relied on as an alternative to proper design: brick creams are not entirely easy to apply – a bit like sun cream, it isn’t always easy to see you’ve missed a bit till it’s too late).

External insulation is likely to be the safest bet in an exposed location, but detailing to stop the rain getting behind the insulation is critical. As well as reducing the risks of horrible internal damp problems, getting and keeping the masonry dry will even, in itself, keep the occupants warmer. The U-value of natural stone may increase by more than 50% when the same material becomes wet.[10] Similar findings have been reported in brick walls, by the manufacturers of a water-repellent brick coating.[11]

Climate change is thought to be likely to increase the incidence of driving rain. Over the coming 50 years rainfall is expected to increase in most of the UK, and wind speeds are generally increasing too.[12]

In his report, Design for Future Climate, architect Bill Gething warns: "It is a mistake to assume that familiar materials will continue to behave in exactly the same ways in a changing climate. Designers will need to have a thorough understanding of the fundamental principles of materials' behaviour and building physics so as to predict behaviour under different climate conditions."

Brickwork is not an impervious barrier; 'Its weather resistance relies on a dynamic process of wetting and drying.' In today's climate it may not become sufficiently saturated to allow significant quantities of water to penetrate far enough to cause problems, however, this may not be the case if winter rainfall and wind speeds increase.

'Routine maintenance/replacement is an obvious opportunity to upgrade to higher standards, and there may also be opportunities to improve weather tightness as part of works to upgrade a building's thermal performance (in response to the mitigation agenda). For example, adding external wall insulation protected by a rain screen could provide a higher standard of weather resistance than the original wall.'[13]

Draughts and ventilation – not the same thing!

Although the effect of retrofit on airtightness can be unpredictable, if uncontrolled infiltration is reduced in a dwelling that already has inadequate ventilation, air quality may suffer. This does not mean that leaving fabric leaky is a 'solution' to the risks of poor air quality and condensation. Fabric infiltration is often conflated with ventilation, but this is unhelpful and leads to some unnecessarily pessimistic attitudes.

You will sometimes hear it suggested that 'a balance needs to be struck' between reducing heat loss for GHG reduction policies, and the need for a healthy air change rate. In these kind of statements, infiltration and ventilation tend to be conflated – as if draughts were an essential aspect of ventilation. This may even lead to the suggestion that fabric should be insulated while being left leaky – despite the fact that this would seriously limit the energy and comfort improvements.

This mindset seems to imply pessimistically, that only by enduring draughts, can you have an adequate fresh air supply – in other words, you can't have both comfort and health. Thinking like this could be unhelpful and even dangerous:

- It may put people off making buildings warm and airtight, by implying this may be incompatible with health – even though it doesn't have to be.
- It implies that unretrofitted, leaky buildings can be assumed to be well ventilated, and so have adequate air quality – when often they do not, and their ventilation should not be left unimproved.

The often-cited trade-off is a false one. Ventilation can work well without any fabric infiltration, and once effective ventilation is in place, improving the fabric airtightness is unproblematic and indeed desirable, and will lead to increasing comfort, energy efficiency – and possibly even to more effective ventilation (because there is more control over air paths). Reducing infiltration also reduces exfiltration – the leakage of warm, possibly moist air through into colder parts of the fabric, where condensation may then occur.

Thus, for example, in the deep retrofit of the listed building described above, architect Harry Paticas specified continuous mechanical extract ventilation (MEV), and undertook extensive draught proofing to increase airtightness to 1.8ach@50Pa, in order to limit heat loss; "We monitored the air quality, and after careful commissioning the relative humidity went down to around 50%; the house is now very comfortable and the clients are very happy." A good ventilation system running in an efficient, airtight fabric does not lead to big energy costs. In the example above, total energy use is pretty well on target for AECB silver, at 40kWh/m^2.a. for heating and 120kWh/m^2.a primary energy. It is sometimes possible to install MVHR in a deep retrofit, offering even more comfortable and controllable ventilation, and with filtered air as well. If the airtightness of the dwelling can be reduced below about 3ach @50Pa, the MVHR can even save energy.

By contrast, even in leaky homes, infiltration plus 'natural ventilation' fails to deliver reliably good air flow and IAQ. In one study of naturally ventilated homes, with airtightness ranging from 5 to 20 ach @50Pa, winter air exchange rates ranged from higher than the recommended 0.4 or 0.5 air changes per hour, right down to a stuffy 0.2 ach. However, the ventilation rate was not closely related to levels of airtightness, but much more to occupant behaviour (mainly window opening).[14]

King is adamant that upgraded ventilation should become an integral part of any funding programme for energy retrofits: "Ventilation has to become a Green Deal and Eco measure. And we have to test it is working as designed."[15]

There is sometimes concern that increasing the thermal performance will lead to the risk of overheating as heat is 'trapped'. In fact insulation (particularly in the roof, but also EWI) can protect against overheating. It is, however, always important to ensure there is effective and safe ventilation – both background ventilation, and the opportunity for 'purge' ventilation, usually via opening windows on two sides of the building.

If windows are being replaced, or walls are being made thicker with insulation, it is important to check that window opening is not going to be compromised. Unless carefully specified, tilt and turn windows, in particular, may offer inadequate openings (especially if subject to opening restrictions at higher levels, to prevent accidents).

One special advantage of MVHR in a well-insulated and airtight building is that when it is very hot outside, the ventilation can be run on heat recovery – or 'cool recovery' -- mode during the day, to limit indoor temperature rises. When the temperature falls again at night, the heat exchanger can be bypassed and the windows opened, so the dwelling can then be cooled down ready for the morning. See graph below.

The golden age of building?

There is sometimes an implied assumption that old buildings work well – by design - and modern interventions tend to detract from their performance. Assuming that draughts are an effective mode of ventilation is just one example of this.

Thus we hear that traditional buildings 'breathe' via the fabric, ventilation and draughts to create a 'safe environment' and traditional buildings are designed to, keep dampness levels in the building fabric below problematic levels by evaporation.

Yet a lot of 'traditional' buildings are cold, damp and unhealthy, suffering from various forms of rot and decay – and buildings, especially those of the less prosperous parts of society, always have been.

One common suggestion is that 'breathing' fabric is important in carrying away the moisture loads generated indoors. But it is not clear if this has ever been critical to maintaining low indoor RH. As we saw above, with a 'breathing' fabric moisture movement can be mainly in the other direction with moisture coming in from outside and needing the ventilation air to carry it away.

In the past, if traditional buildings achieved a 'healthy' moisture and ventilation performance, open fireplaces are likely to have played a big role. A constant, vigorous draught (all year round, but especially when the fire was lit), will have removed far more moisture than would ever have passed from inside to outside though a 'breathing' fabric. Now that the open fireplace is generally a thing of the past (decades past, in most dwellings), alternative moisture removal strategies are essential.

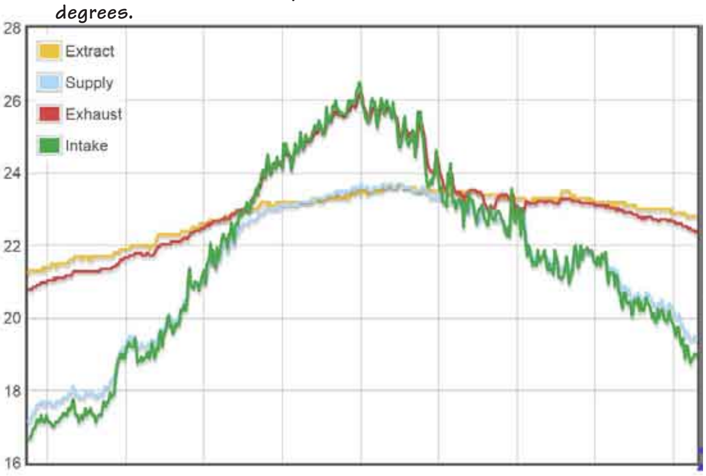
The value of hygroscopic surfaces in buffering hour-to-hour fluctuations in indoor moisture is a different issue – but hygroscopic surfaces can't remove moisture either. Hygroscopicity can also have a role in dealing with dampness that penetrates into the fabric, as we saw above. However, it is often hygroscopic and/or vapour open materials that are letting the moisture in, in the first place. Traditional building materials don't automatically solve all damp problems! Generalisations can be unhelpful.

Pre-remediation

When a retrofit has been designed as a whole-house retrofit by a designer, in a holistic way, it is much more likely that repairs and remediation will be carried out as part and parcel of the retrofit. As we discussed in the previous article, the time for repairs is often the likeliest opportunity for a whole-house retrofit, and makes practical and financial sense a lot of the time.

While not everyone is in a position to strip back the entire fabric to check and replace every last bit of potentially deteriorated timber, there are clearly some basic checks and repairs that should take place. Timbers should be assessed if retrofit is going to change their hygrothermal environment – or simply, render them less accessible. Pointing and rendering should be checked and if necessary, upgraded to be better at shedding liquid water and letting water vapour through. Faulty rainwater goods and poor ground drainage should be tackled in advance – in some situations drying may be faster before retrofit measures

MVHR, airtightness and external wall insulation working together to keep the interior of this stone cottage (yellow line) at a comfortable 23 degrees, while the temperatures outside (green line) climb to 26 degrees.



are installed. While retrofit should always allow continued drying, energy retrofit on its own shouldn't be expected to dry a wet structure and, whatever the other measures proposed, we also saw above any house that is having money spent on it should have the ventilation assessed, and upgraded if necessary.

Heritage and the need for give and take

If the 'tension' between airtightness and health is something of a false dilemma, the conflict between conservation values and energy efficiency can be felt very tangibly. While energy efficiency and good ventilation both benefit the building occupants, heritage issues may, on occasion, set one group's priorities in conflict with another's, with occupants potentially paying the energy bills – or suffering the discomfort - imposed on them by conservationists' priorities.

A comment on a petition about listed buildings[16] read: "I am an owner of a Grade II listed money pit. Our Georgian sash windows are due for replacement. They were replaced in 1975, there is no crown glass, spirals instead of lead weights, 32mm bars ie nothing original at all. We have asked for permission to have double glazed, timber slimline replacements, but, once again double glazing appears to be the most hated invention as far as conservation officers are concerned. The temptation just to put them in and say 'to hell' with conservation officer is massive."

Another added: "After 25 years of living in a Grade II listed building our experience has been that the definition and application of Grade II listing of private residential buildings is: unfair and contravenes human rights; unnecessarily restricting and expensive; subjective and opinionated; arbitrary and inconsistent. Its outcome is environmentally unfriendly, criminalising and counter-productive." It is not just listed buildings where these problems arise. Since the introduction of CESP, a number of pretty humble pre-1919 terraces have been fitted with external insulation, and this too has attracted criticism.

A report in the Architects' Journal began, "Edwardian and Victorian homes in less affluent areas are seen as being at risk of 'aesthetic harm' " because intricate features on terraces were being lost after external wall insulation.[17]

Unfortunately leaving the 'intricate features' uncovered is a very unsatisfactory compromise, as Nick Heath pointed out at Retrofit Live, "The planning department sometimes promotes thermal bridges because they insist the installers leave the features untreated." Leaving the 'intricate features' exposed also introduces weak points where water ingress may occur.

Conservationists sometimes suggest that 'there are lots of other ways of improving energy efficiency'.[18] However, to achieve the kind of deep retrofit that robustly reduces energy consumption, carbon emissions and bills, while increasing comfort, wall insulation is generally necessary. However, when people don't have the luxury of living in one house while retrofitting the next, the disruption incurred from installing internal insulation is almost always unacceptable, and installing IWI to the necessary standard may be more expensive than even well-executed EWI.

Where mass-scale EWI has been carried out on pre 1919 terraces, the reaction from the occupants has tended to be favourable – both about the improved comfort and energy efficiency, and about the appearance.

In some cases, the insulation retrofit has taken place specifically as a regeneration measure, as an alternative to demolition. In these cases, as Nigel Banks of Keepmoat points out, the EWI could itself be seen as a valuable agent of conservation. Buildings, street patterns and, crucially, homes and communities, are all conserved.

BRE's King wonders about the merits of getting hung up on the traditional appearance of homes that are miserable to inhabit: he points out that while there are people who really love traditional working class terraces, "they aren't always the people who live in them".

"If you ask the occupants, they will often tell you their house is horrible, cold and damp". So when people say "we have got to protect the character of these streets" that's not the occupants who can't afford to heat their home. "They like their neighbourhood and community, not the houses," he says.

There is an important question to ask here. Historic buildings hold great charm for many of us, and may have meaning for some who live or work around them. But how much should other people be expected to pay for our delight with their health – and their energy bills? And how much should the planet pay? This seems to be a discussion we need to have.

We know a lot about what not to do ...

Until recently there has been next to no research into the behaviour of moisture, in particular, in solid walls – and even their thermal properties are not well characterised - -

Leaving the decorative band at the top of this wall exposed has created a large thermal bridge, and may increase the risk of rain penetration. Courtesy NDM Heath Ltd though a number of people are now working on this as we saw above.

Because U-values are affected by moisture content – and also by wind speed, even orientation makes a difference: “A building with four walls will have four U-values,” warns King. The right data for a given situation are very hard to find at present, making modelling less reliable that we would like, and meaning larger margins of error have to be built in – which may be costly in terms of materials or performance.

Given some of the poor workmanship described above, it is not entirely surprising that there have been problems following retrofit. Exactly what has gone wrong and why is not always clear though. As King explains in relation to EWI: “We think we understand what is happening in these problem installations from our modelling, but we are also testing this out on site. There is virtually no data out there about what actually happens in insulated walls, it’s shocking it has not been measured."

Some of this badly-needed research is now, finally , happening; “Now we are watching the installation we can follow the story right through, from before, then watching exactly what is done, then monitoring afterwards. We have to keep an open mind and follow these installations through, tracking the process.”

Meanwhile a number of AECB members are monitoring moisture movement in retrofitted buildings. This research is informing the 'moisture safe' aspects of the forthcoming Carbonlite Retrofit training.

This article has mainly looked at issues with solid wall insulation, but walls are not, of course, the only vulnerable part of a building fabric. Any element can be damaged by careless or inappropriate building works, including those works being carried out with the intention of improving the energy performance.

Floors, and in particular, suspended floors, can be tricky too – no-one wants a cold draughty floor, when they have carefully insulated the roof and walls and replaced the leaky windows – but has the floor, like the walls, been drying into the living space? If the floor is insulated and the joists get cooler, will they be at risk of condensation? And what about rising damp? Some people claim it barely exists, some assert it can be dealt with by 'breathing' constructions allowing the damp to evaporate, others prefer to attempt to stop the damp before it has climbed up the wall.

There is possibly less basic research under way on floors than there is for walls, though there is a notable example at UCL, where researcher, Sofie Pelsmakers, is studying temperature and humidity beneath insulated and uninsulated suspended floors in Victorian buildings, to assess the moisture and mould risks of various approaches.

We aren’t standing still

In the light of some of the very poor installations that have taken place, some organisations are also taking steps to avert the errors we do understand. For example in Blackpool , where some of the installations reported on by Nick Heath are located, the city council has commissioned Heath and colleagues to help them develop a decision making tool and installers’ code of conduct, to include some quality assurance, to try to improve matters in future. Similarly, the Centre for Sustainable Energy in Bristol has developed retrofit advice for local authorities, being published this summer.

One of the issues with ‘bulk buys’ of solid wall insulation in particular is that the insulation is sold as a 'system' – with installers often trained and accredited by the manufacturer -- and it is hard to improve the specification within the terms of the system guarantee. However some manufacturers are introducing products that help deal with thermal bridges: for example, low profile insulated components to fit behind rainwater goods, insulated flashings, and so forth.[19]

And at government level, researchers, manufacturers, and representatives of the construction industry and of DECC and DCLG are working together to share understanding of the issues, and to improve practice – no-one wants to be presiding over a disaster, such as was seen with faulty timber-frame designs in the 1970s. The process is already bearing fruit, the Retrofit Live event heard – for example, the moisture guidance for Part C is expected to be updated.

BRE's King reminds us that Ofgem, as the regulator of energy company funding for retrofit (under ECO) also has the power to enforce much higher standards, and he and colleagues are actively lobbying them to do this; 'Yes, we have to be careful, but let's not throw the baby out with the bathwater.'

All the issues above could be worrying for someone who is getting involved in building retrofit. And it isn’t always easy to tell whether a particular view (including what you have read here!) is based on sound science, on experience, or on sincerely held but unsubstantiated opinion. It can be confusing when 'experts' appear to disagree.

As we saw above, there are a number of people actively carrying out empirical investigations and trying to learn more, including from some of the more obviously flawed installations; this work is invaluable, as studying real world buildings is the only way to know if the models we use are any good.

The advice from most of those involved in this research seems to be that the most important thing is to go into the process with your eyes open, rather than taking a 'fit and forget' approach. Find out what you can about the potential risks, and take account of them throughout design, installation and post-occupancy use of the building.

Whether it's a one-off retrofit or a community - or estate-wide programme, designer and client should understand there is no certainty. An interested designer will, anyway, want to know how the installation performs over time, and should look for ongoing feedback – even simply informally via aware occupants, or better still by formal monitoring. But do go into it! Carefully designed and monitored retrofits are demonstrating that even in unpromising locations (such as listed buildings suffering from saturated masonry) deep, holistically designed retrofit can transform comfort and energy performance, without causing fabric or health issues.

BRE's Colin King agrees that we should carry on, keep our eyes open, and keep learning; deep retrofit is the right thing to do. Although he has been horrified by many of the EWI installations he has inspected, he comments: "I don't want to colour my views just because I get called out to see bad examples." He has not despaired of retrofit; quite the opposite: "People are living in shabby, old, wet houses. We do definitely need to do something, we just have to be careful."

Go deep

SAP is not a good tool with which to design a retrofit, even though SAP or even RdSAP is the sole criterion on which much retrofit is currently judged and funded. But SAP cannot reveal the true benefits of deep retrofit. As we saw in the second article in this series, it is deep, holistic retrofit that delivers the better value in terms of carbon and running cost savings, once occupant comfort is allowed for.

Deep, holistic retrofit is more likely to consider the whole fabric, to include assessment of fabric condition, of ventilation and airtightness, and to consider all the building elements and those critical junctions between them. When this is done well, the savings in fuel costs and carbon are just one facet of the many benefits that can flow.

Putting people at the centre

As Neil May of the STBA put it at the Retrofit Live event: "People have taken too low a profile in retrofit up to now. It's just been about energy." This is echoed by King: "Retrofit is about creating a better environment for people to live in. We should be measuring improvements in health and wellbeing."

The advantage of putting occupants at the heart of the retrofit is that many of the perceived 'conflicts' or 'trade-offs' disappear. If the goal is to create a healthy home environment, comfortable living temperatures and good ventilation in a sound fabric become the non-negotiable basics. Having set that baseline, you then go on to deliver these basics in the most comfortable and efficient way that ingenuity can devise – but never taking your eye off the occupant. And really, how could you justify doing anything else?

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Refs

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3. Centre of Refurbishment Excellence, April 2015

4. "This standard deals with critical surface humidity and interstitial condensation, and does not cover other aspects of moisture, e.g. ground water, precipitation, built-in moisture and moisture convection ..." and warns that "the much greater risk of condensation occurring" is " as a result of air leakage...as well as the effects of exposure to sunlight, clear night skies, wind and driving rain, particularly in exposed positions". (BS 5250:2011 Code of practice for control of condensation in building)

5. Draft of this guidance can be viewed at: http://stbauk.org/what-we-do/index

6. See for example http://tiny.cc/lwpgzx

7. RetrofitLive, 2015

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17. http://tiny.cc/trpgzx

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