Airtightness in retrofit

A case study

Renovating and retrofitting an existing property is challenging for so many reasons. When you add the requirement for airtightness to this it throws up a whole new bunch of challenges and expectations, many of which builders are still to learn how best to approach. Kate Ball has kindly taken the time out to tell us of some of those challenges and how the design and build team helped her achieve the objectives that she had hoped for ...

19 Thornhill Road is a detatched 1950s house retrofitted to EnerPHit standard (pending certification) with extensions from the 1980s and 2012, and an attached garage. The clients, architects and builders had no prior experience of Passivhaus standards or highly airtight building.

The final air test result of 0.32ACH demonstrates that good airtightness can be achieved in retrofit, even with a novice team, provided that the strategy is very carefully thought through and followed.

Training the team for airtightness

It was initially difficult to convince all parties involved that airtightness would be the most difficult element to achieve, leading to some weak areas being present in the design as we started on site. In particular, the initial floor-wall junction plan had been to leave the original skirting as a marker for the new floor slab level, to tape the damp proof membrane to the walls with airtight tape and use expanding foam to fill any gaps. It pretty rapidly became obvious that this was going to make some very weak junctions, not least because the concrete pour resulted in quite a bit of DPM movement, leading to various folds which were impossible to tape fully.

The pre-retrofit frontage of the property but with the new windows in place ready for the parge coat and external render.

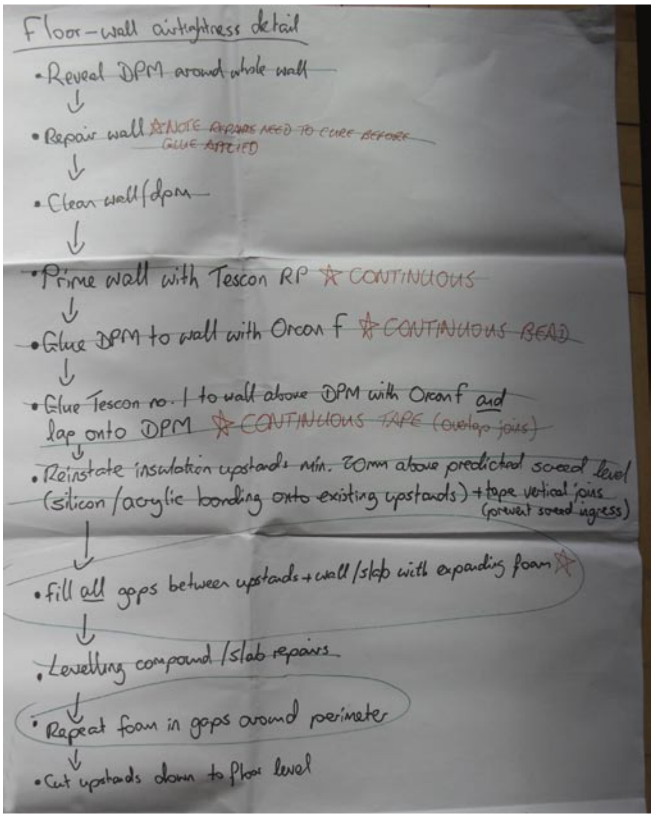
Paul Jennings, the air tightness expert, ran a training day during the early stages of the build, after which even the most sceptical members of the team were convinced about how seriously airtightness needed to be taken. Luckily, this was before anything irreversible had been done - though having the training during the design stages would, in retrospect, have been better. During the training the blower door showed >10ACH with breezes blowing through all the plug sockets, which did a lot to convince everyone that getting a result below 1ACH would really require concentration.

The main build team was small, so with myself as airtight champion, site supervisor and client living on site (albeit with small children in tow), it was possible to ensure that everyone involved in the build was adequately trained regarding airtightness. Where subcontractors appeared erratic in their performance, it was possible to provide very close supervision to avoid or resolve issues as they arose. I found that regularly distributing cups of tea was a very effective, but friendly way, of keeping a close eye on everything that was happening.

Design stages

The design for airtightness was adapted from case studies and information from the AECB and related links, particularly the Grove Cottage information provided by Andy Simmonds, and Paul Jennings' (ALDAS) 12 steps for airtightness.

The logistics of installing all the airtight elements in such a way that the layer would end up continuous were complex, requiring some strips of airtight membrane or sealing to be installed at very different stages of the build from the rest of the area they attached to. The airtight sequencing was worked out using the architect's drawings, lots of wandering around the house, large flow charts and quite a few sleepless nights. The charts allowed me to ensure that crucial moments were not missed by joining together all the separate elements of the build in a logical way. For example, to make installing the extension roof and wall airtight membrane possible, the membrane had to pass between the roof beam support and the beam itself - but before there was a frame there to staple the wall or roof membrane onto. This was achieved by installing a double square of membrane under the beam, then later taping it onto the corresponding airtight layers as they were installed. We have also pre-installed solar thermal



Rough flow chart outlining the procedure towards achieving airtightness for one of the elements of the project.

pipework through the roof airtight layers and insulation, with the intention of installing panels when we can afford them.

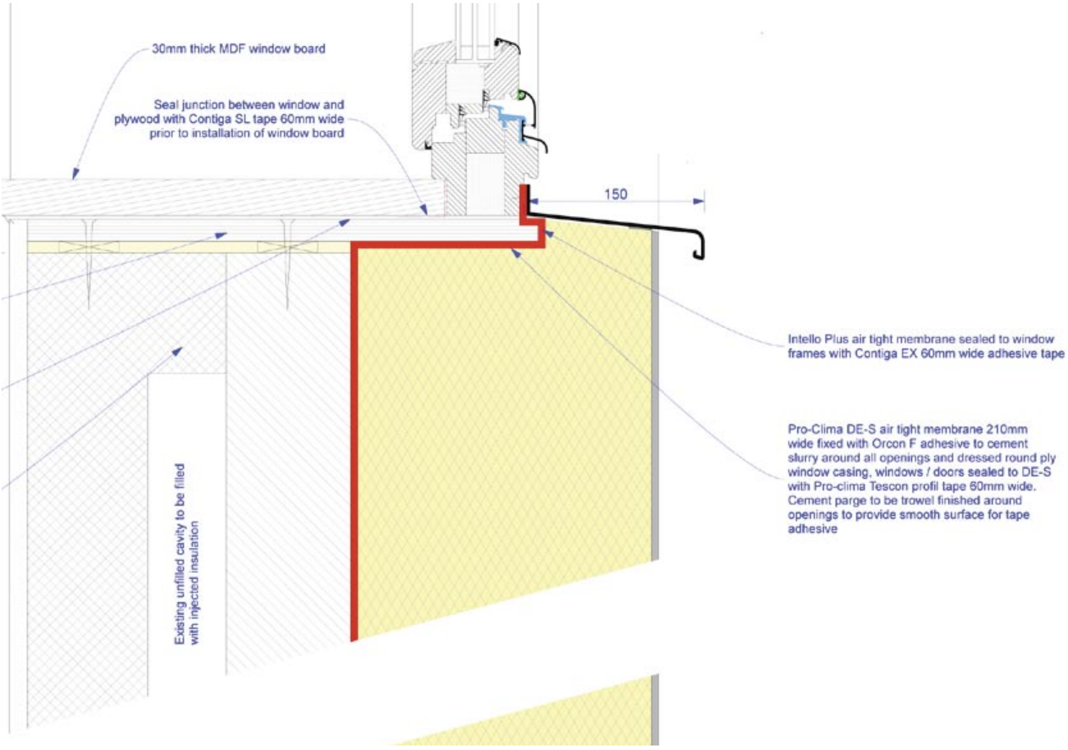
Early builder involvement allowed us to eliminate many issues for thermal bridging and airtightness, such as joist penetrations, and to ensure that the airtight layer would be as continuous as possible.

As clients, our lack of experience in reading architects' diagrams led to a few misunderstandings which could have been a real problem without help from the builders. For example, the original structure of the timber framed extension would have had the ceiling binders attached to the roof I beams - fine under normal circumstances, but disastrous for the airtight layers since every binder would have gone through them. This wasn't obvious from the initial details, but the builders' understanding of construction allowed them to spot it before it was too late. Dropping the ceiling binders by 30cm or so onto joist hangars removed the penetration problem, improving airtightness and thermal performance (more insulation, less timber), albeit at the expense of some room height.

The most difficult element of the project to design for airtightness was the cavity walls, which were already mostly filled with mineral wool. It was not financially viable to empty the cavities and re-fill with a more airtight insulant, as was done at the Totnes Passivhaus, so it was crucial to ensure that the cavities would be sealed sides, top and bottom. Cavity closing where joists crossed the top of the cavity on the flat roofed section of the house was particularly difficult. This was resolved by levelling the brickwork with polymer modified cement, cutting sections of OSB to fit between the joists, and sealing everything using airtight glue and tapes to the brickwork on both sides of the cavity.

We chose to keep as much as possible of the airtight layer external to avoid damage during future decorating works. The internal plaster is solid, and does provide a

In this main photo we can see many of the details discussed in the design stage. The parge coat that was applied over the masonry; the external insulation and the detailing of the window boxes. The internal view of the window box can be seen in the inset photo above.



Section through a typical wall/window junction. The airtight layer can be clearly seen in red.

secondary airtight layer, important particularly for the floor-wall junction, but we realised that future-proofing required that, as far as possible, airtight elements should be difficult to reach and damage during future furniture installation and decorating works.

Details

Throughout the project the weather was a significant problem, but with careful design and installation timing, the wind and rain did not degrade the airtight layers too much.

The main airtight layer on the brick walls is the external cementitious parge coat: The internal wet plaster is a secondary, imperfect layer. The external wall insulation itself consists of two cross-bonded layers of EPS. All joints are filled with phenolic foam, and the render coats are continuous and sealed to the windows and doors. This sounds airtight - but isn't. Aside from the flaws in installation (of which I'm sure there are many - the installers needed extremely close supervision to work to spec. The insulation is unavoidably unsealed where it hits the roof gables or goes between the I beams into the roof insulation at the eaves. The parge coat was therefore essential.

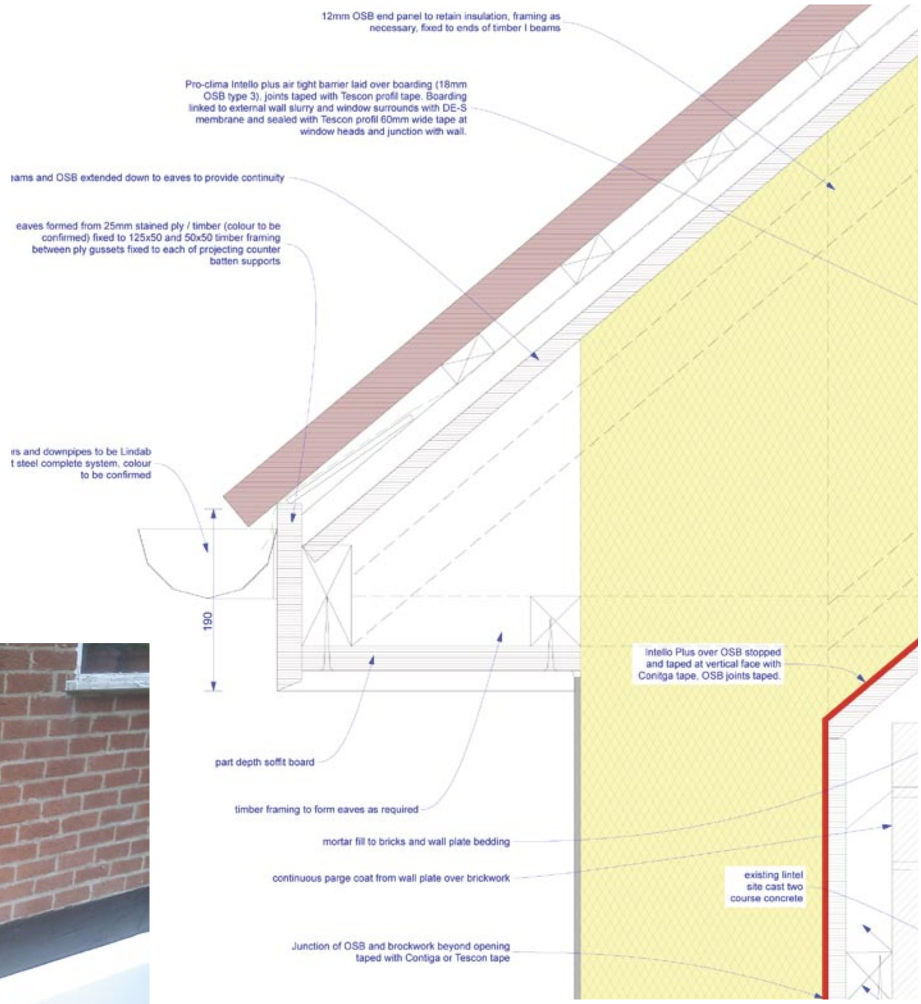
The timber framed walls have a double 18mm OSB/ Intello membrane airtight layer external to the stud frame, with the membrane sandwiched between the studs and the OSB to prevent movement tearing the nail holes. As such, the airtight layer is at least 100mm from the internal wall of any room.

The pitched roofs again have a double OSB and Intello airtight layer, with Intello external to OSB so the membrane

Penetrations through the outside walls had to be very carefully detailed and executed to ensure that the airtight layer was kept absolutely intact.

Right: section through a typical wall/roof junction. The airtight layer can be clearly seen in red but it was also essential that the insulation was continuous between the element changes.

Below: view of the insulation detailing below DPC level and underground.



cannot sag under gravity or be damaged by people in the loft spaces. This crossover from the membrane inside (walls) to membrane outside (pitched roof) caused the logistical difficulties with membrane having to pass between the ridge beam and its support during the construction of the extension.

The flat roof has exactly the same order of elements as the walls - the reverse of the pitched roof, due to the slightly different damage risks. Not least, there are joists, insulation and plasterboard protecting the flat roof membrane internally, whereas the pitched roof airtight layer is exposed in the loft spaces. Also, the pitched roofs will not be walked on, whereas the green flat roof will - which would present a risk of movement causing friction damage to a membrane placed above the OSB.

The floor-wall junction is our weakest main junction. Since we were not re-plastering the whole house, we used wide airtight tape with primer and glue to tape the concrete floor slab to the existing plasterwork, bracing the tape with marine ply to support below the damp course and provide fixing points for the skirtings. The airtight layer is protected by the skirtings and new floor coverings.

Windows and doors are boxed out into the insulation with 18mm ply (the doors are braced from beneath using Compacfoam high density polystyrene). The ply is sealed to the units with tapes externally and internally, and into the parge coat and plaster externally and internally.

Testing

Since absolute values of airtightness seemed unimportant during the build, we chose to hire a blower door kit for a week to carry out elements' testing rather than having a formal preliminary air test. This allowed us to check the airtightness of the windows, doors, roof and new timber walls before any internal plastering or external wall insulation would have made repairs difficult or impossible. In the event, we found few leaks that we had not already anticipated and marked for repair, though in our novice state we were concerned that this meant we'd done something horribly wrong somewhere. Interestingly, as the parge coat was completed during that week, we discovered that the un-parged solid brick gable end let through more air than the newly-drilled MVHR pipe holes on the same parged gable end a day later, which was fairly amazing.

The final air test was carried out by Paul Jennings, using a window-mounted fan to remove the paradox that while doors are often a major source of leakage, one door is usually eliminated from testing by mounting the fan into it. With no real idea at all what our result would be, the whole team were extremely pleased to find out we'd made it very respectably below the 1ACH required for EnerPHit certification.

Regardless of how well the work is carried out, every home has to be pressure tested after completion to ensure that no parts were omitted in error. The fan was mounted in a window so that all doors could be air tested properly.

Lessons learned

In spite of understanding the risk to airtight materials posed by water, we took the risk of not enclosing the house in water tight scaffolding. This was a mistake, and given the appalling weather in 2012 caused considerable delay to the build. It would have been financially (and emotionally!) viable to get the cover - particularly since we could then have offered rooms to housemates considerably sooner than we have been able.

Having a double airtight layer of taped OSB and Intello membrane over all the timber framed walls and the roofs has probably been essential to achieving airtightness. In particular, lakes of water collected on the Intello layer of the flat roof before the waterproofing was installed. The flat roof and its airtight layers had to be installed before the external wall insulation, but the flat roof insulation and the bulk of the waterproofing had to go on after the external wall insulation. This led to the airtight layers being protected only by tarpaulins for a few very wet weeks, so the OSB sat wet, and the Intello had to be slashed from below to allow the water through. I suspect that the OSB is now significantly less airtight than it would have been- but the roof airtightness has been maintained by re-taping the cuts in the membrane. Amazingly, the Intello and its Tescon tape joints survived, demonstrating that the airtight tapes are able to maintain integrity even if they get wet, provided that they are installed onto dry substrates (we did do the obvious experiment - the tapes wouldn't even temporarily stick onto damp substrates).

The almost completed building now shows little sign that it is so much more airtight and highly insulated than neighbouring homes. The masonry porch is built outside of the airtight and insulated space.

Working around the features of an existing building meant that airtight details were very fiddly in places- particularly working on three-dimensional internal corners and where multiple membranes had to meet at strange intersections. We found that neat, and so airtight, joins could be achieved by keeping the membranes across all plane surfaces flat and smooth, then cutting back all excess membrane and taping the resulting edges together layer by layer - on occasion even taping the first section of membrane to an underlying flat surface to give a secure, smooth substrate to tape the next pieces of membrane onto. Trying to origami fold membranes at intersections to create a junction without cutting excess off, was definitely not a good plan.

In common with other projects, and in spite of following to the letter all requirements for protecting them from weather, the weakest elements of the build for airtightness are the doors. With careful adjustment we have eliminated almost all of the leakage from around the frames (one door still admits the odd ant through the join in the seals- incredible in a house this airtight), but the holes the locks and handle bars are installed through are unsealed. We hope to be able to resolve this with careful adaptation of grommets before next winter; removing the facing from the handles is proving a trickier task than anticipated, complicating the task.

Kate Ball

Kate is a full-time, home educating mum with an interest in sustainability and ecology. She lives with her husband, kids and two housemates in a recently EnerPHit retrofitted house in Derby, and runs voluntary sessions on energy efficiency and groups for home educated children. Before having kids, she taught secondary science. Free tutorial sessions and open days at the house are advertised through the Superhomes network at:
www.superhomes.org.uk