

DEMYSTIFYING AIRTIGHTNESS

GOOD PRACTICE GUIDE: JUNE 2020



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About this guide

What is this guide about?

This document provides general guidance on the design, procurement and installation of air barriers for any building that is intended to be airtight.

Who is this guide aimed at?

Construction professionals involved in Passivhaus developments. Architects, architectural technicians, engineers, design managers, project managers, contractors and consultants.

How to use this guide?

This guide is split into three main sections. The first is a brief overview of the main issues and considerations around airtightness. It is an 'Introduction to Airtightness' to help ease the reader into the more in-depth content in Section 2.

Section 2 provides detailed guidance on airtightness considerations by RIBA stage, and should ideally be applied stage-by-stage in an airtightness project. Not all of this guidance will be relevant for smaller projects, but it is considered to be best practice.

Section 3 is aimed more at designers of airtightness details and contains detailed information, examples and tips for common junctions and construction details.

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The Passivhaus Trust would like to thank the following individuals and organisations for their contribution to this report:

Reviewers:

Alan Clarke
Sally Godber WARM: Low Energy Building Practice
Nick Grant Elemental Solutions Ltd
Kym Mead Mead Consulting Ltd
Mark Siddall Lovingly Engineered Architectural Practice (LEAP)

SECTION 1

Overview



Why is airtightness important?

Airtightness is important for many reasons, including reducing heat loss, improving comfort and protecting the building fabric. Airtightness is achieved by sealing a building to reduce infiltration – which is sometimes called uncontrolled ventilation.

Airtightness is measured by monitoring the amount of air that escapes or enters a building at a pressure of 50 Pascals. For Passivhaus calculations, this measurement is expressed in air changes per hour (ACH) i.e. the number of times an hour that the air in the building changes when it is pressurised (either negatively or positively).

UK Building Regulations express this in a slightly different way as the volume of air that escapes per m² of external surface area, also at 50 Pascals of pressure. This is sometimes referred to as Air Permeability.

Heat loss

Once the insulation levels in a building have been increased and the thermal bridges dealt with, heat losses from ventilation become significant. As shown in Figure 1, ventilation heat losses can account for a large proportion of all heat losses in a low energy building if airtightness is not considered.

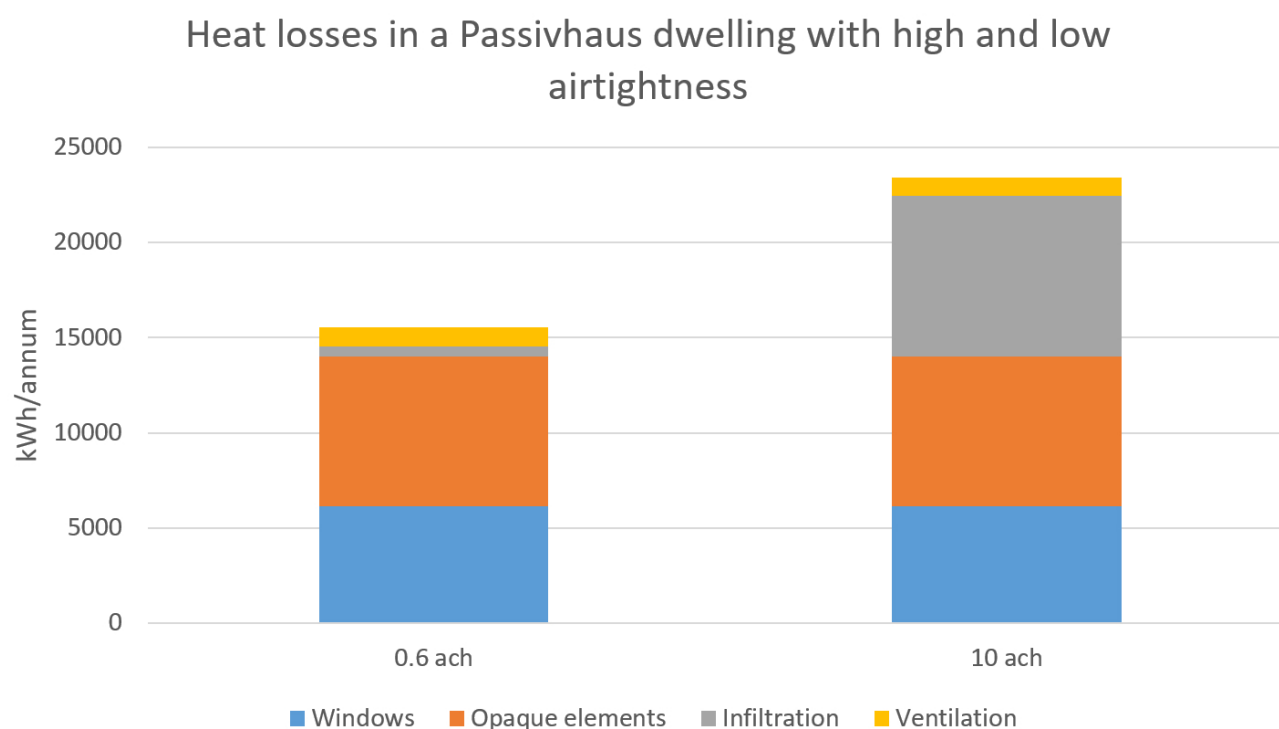


Figure 1 Graph showing heat losses in a domestic property broken down by ventilation, building fabric and windows. The dwelling is assumed to have a mechanical ventilation system with heat recovery. Without this, heat losses through ventilation and infiltration could be much higher.

Improving comfort

Infiltration is the air leakage through the building fabric. It is uncontrolled ventilation, and can lead to drafts. When the air outside is colder than inside, this leakage can be very uncomfortable. Air velocity is one of the basic indicators of thermal comfort. Movement of air at just 0.1m/s can be felt as a draft in cold climates in the winter¹. Improving the airtightness of a building is therefore likely to improve comfort.

Protecting the building fabric

All buildings should be airtight. This is not the same as being moisture closed, non-breathable or vapour impermeable. Airtightness is important as it protects all building fabrics from the moisture in the air. Movement of moisture by bulk air movement can carry far more moisture than vapour diffusion and if this air enters the building fabric, then interstitial condensation may occur.

How does Passivhaus compare to other standards?

The Passivhaus standard is typically ≤ 0.6 ACH @ 50 Pa. For retrofit the limiting threshold is the same, but a backstop of 1 ACH is permissible if the target is missed and remedial works have been undertaken. Figure 2 shows the maximum permissible size of gaps or holes in 1m² of the external envelope for a Passivhaus and other standards.

Relative air leakage area per m² of external envelope (1:1 @ A4 for 1m²)

Passivhaus 0.6 ACH



EnerPHit 1 ACH



AECB 1.5 ACH



Building Regs Notional Building 5 m³/m²/hr



Building Regs Backstop 10 m³/m²/hr



Figure 2 The area of the circles represents the air leakage area for each building standard per square meter of external envelope. If printed at A4, these areas will be actual size.

¹ https://www.designingbuildings.co.uk/wiki/Indoor_air_velocity

Designing for airtightness

Fundamentally, the air barrier of a building comprises a set of elements that work together to deliver airtightness. These should be considered iteratively throughout the design process. The air barrier comprises products and installation processes that:

- Form an airtightness layer in the floor(s), walls and roof (or top floor ceiling)
- Seal the doors, windows and rooflights (if applicable) to the adjacent walls or roof
- Link the interfaces between walls and floor and between walls and roof, including around the perimeter of any intermediate floor
- Seal penetrations through the air barrier, including
 - » Waste pipes & soil pipes
 - » Ventilation ducts
 - » Incoming water, gas, oil, electricity, data and district heating, as applicable
 - » Chimneys and flues, including air supplies to wood burning stoves or similar
 - » Connections to external services, such as entry phones, outside lights, external taps and sockets, security cameras, satellite dishes

Simplicity is key in airtightness design. The fewer junctions, balconies, dormer roofs and other features, the simpler the airtightness design will be. The images below show a simple design with straightforward airtightness junctions, and a complex design with multiple junctions. Some features can be added after the basic shell of the building has been designed – for example, balconies are less likely to affect airtightness detailing if they are externally supported.



Figure 3 Two contrasting designs for a domestic property. The one on the right would be far more challenging to make airtight.

What can go wrong?

The UK has recently seen the completion of some extraordinarily airtight Passivhaus buildings, both domestic and non-domestic. A zero leakage dwelling (i.e. < 0.05 ACH @ 50 Pa) was achieved for the first time in the UK early in 2019. Experienced teams (architects, contractors and specialists working together) are regularly achieving airtightness values of < 0.3 ACH @ 50 Pa, just half of the normal Passivhaus airtightness target.

Yet at the same time airtightness is the thing that most commonly goes wrong in UK Passivhaus projects. Incomplete or inadequate design for airtightness is compounded by contractors lacking the appropriate site culture, without the necessary skilled operatives and management teams. This leads to delays, cost penalties and, in extreme cases, the failure to deliver a satisfactory level of airtightness.

Unlike the current building regulations, Passivhaus requires that 100% of builds are tested, both new and refurbishment. Generally, there will be one or more preliminary tests and a final acceptance test. Passivhaus testing involves both pressurisation and depressurisation, which facilitates leak detection and is also more representative of real-world conditions. The average of these will give the final airtightness result.

The nature of Passivhaus is that it applies an absolute quality standard, both for airtightness and a range of other factors such as overheating. It is also absolutely evidence based; there is no scope for the uncertainty that sample testing leads to in volume housebuilding in the UK.

For major builds, airtightness coordination throughout the project will require the expertise of an airtightness specialist to ensure the process is effectively managed.

Airtightness is often considered to be the highest risk aspect of achieving Passivhaus certification as it is commonly perceived to be extremely difficult. However, this is primarily due to a lack of knowledge and expertise in the UK construction industry. With careful design and attention to detail both on and off site, and familiarity with the techniques and processes detailed in this guidance document, the risk of failing to meet the Passivhaus airtightness target can be dramatically reduced.

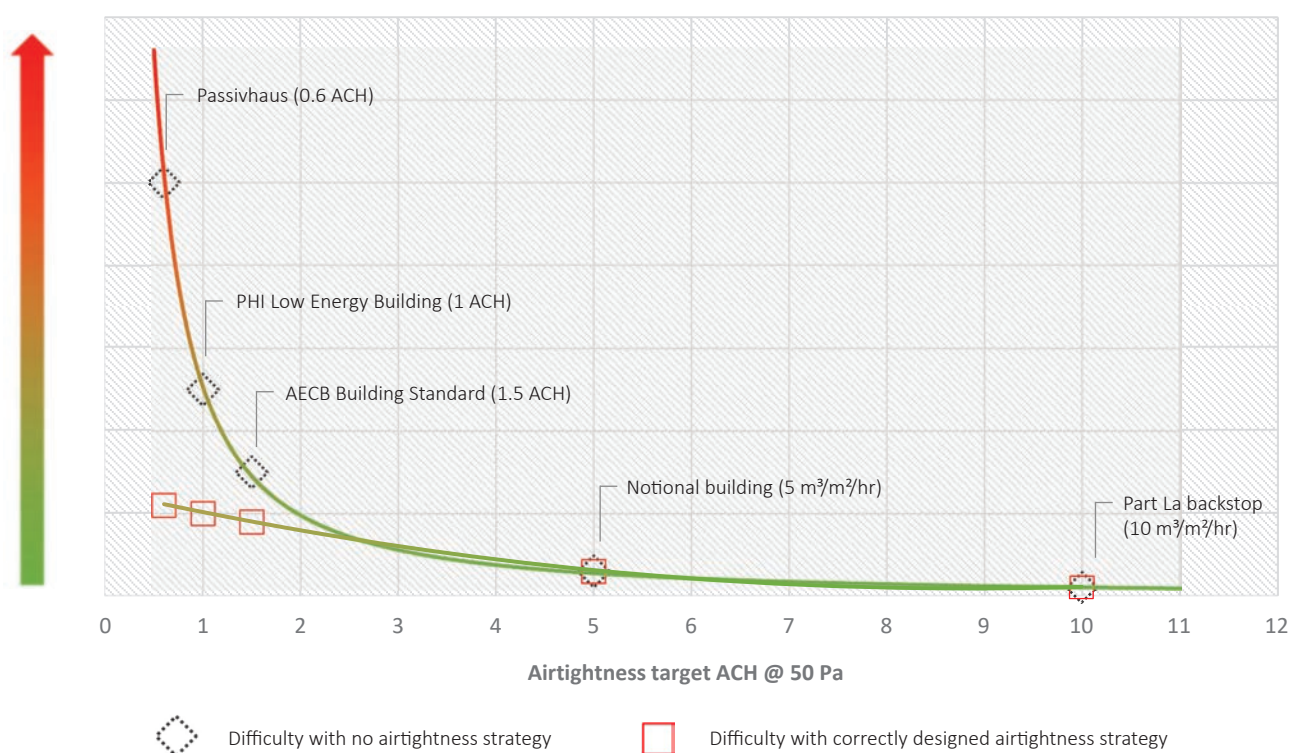


Figure 4 Graph of the degree of difficulty in achieving Passivhaus levels of airtightness currently in the UK

Six key things to get right

The diagram below summarises the six key steps that are fundamental to achieving an airtight building.

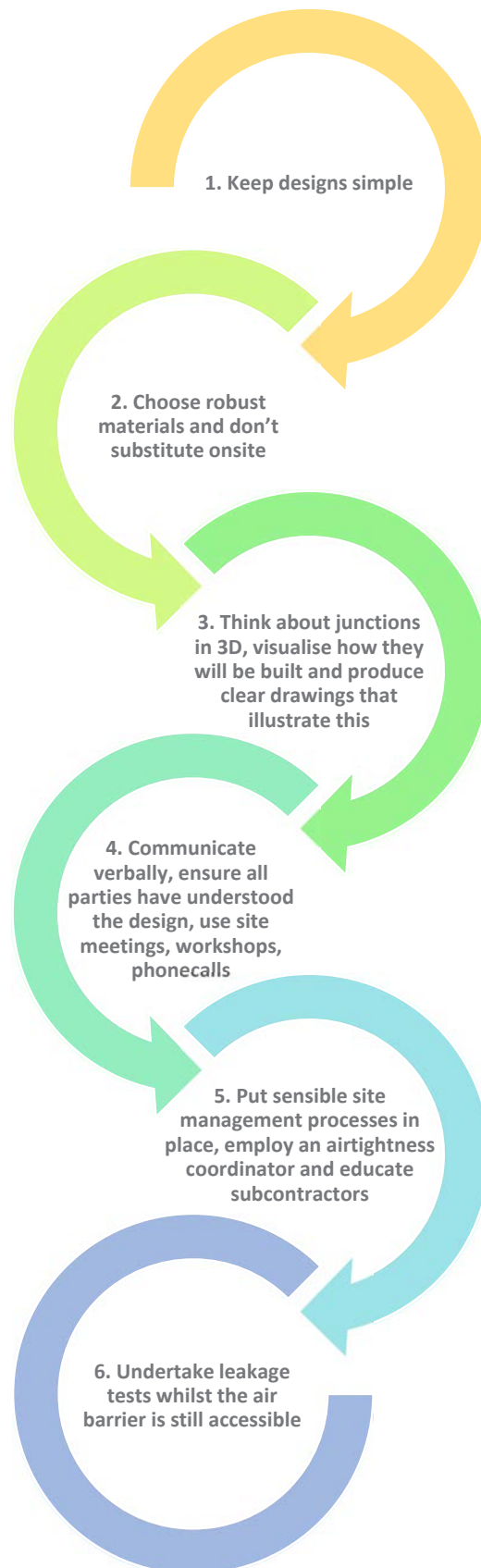


Figure 5 Six key steps to success

Concept design principles

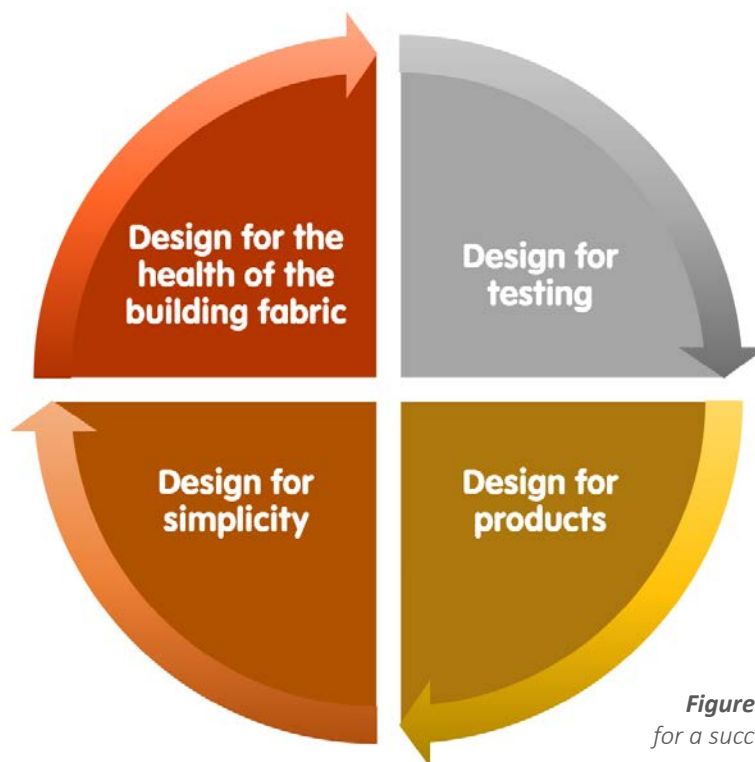


Figure 6 Concept design principle for a successful airtightness strategy

Design for the health of the building fabric

As was mentioned earlier, the airtightness layer does not just reduce energy demand. An internal air barrier prevents warm internal air from moving into the building construction, cooling down and increasing the risk of interstitial condensation. This is different from a vapour control layer that prevents vapour diffusion. Prevention of vapour diffusion and moisture risk management should have their own design strategy, but may have overlapping elements with the airtightness strategy.

Best practice is therefore to install the air barrier on the warm side of the insulation. In some cases this can be between the structure and the insulation – such as when external wall insulation is installed in a retrofit. A wind barrier on the outside of the insulation is not an air barrier in this sense, although generally necessary for a PH project.²

Design for airtightness testing

Consideration of the sequencing of the interim and final airtightness testing must form part of the airtightness strategy. Ideally, the airtightness layer within all elements (walls, roof, floor) should be tested while it is still accessible and therefore when remedial sealing works can be carried out if necessary. If this is not possible, for example in larger projects, the effectiveness of the airtightness strategy can be checked by sample-testing small sections as the project progress.

Testing of multiple properties, or units within one building, can be complex if the air barrier has been designed around the whole building. For example, access to flats may be via an external or internal stairwell, possibly also an access balcony or an internal corridor. If flats can only be tested individually, then the airtightness layer should be designed within each flat. If the airtightness layer is around the whole building, and the flats can only be tested individually then co-pressure testing of two or even more adjacent flats may be required. This is complex and can be difficult, time consuming and costly.

² See BS 5250:2011+A1:2016 *Code of practice for control of condensation in buildings* for more on the relationship between airtightness and moisture control in buildings.

Design for simplicity

Consider the installation of the airtightness materials selected and the experience and skill set of the contractor. For example:

- for large spans of roof, it may be easier for the contractor to install an airtight board rather than a membrane.
- many contractors are familiar with a plaster finish on traditional brick and block walls, so this could be the air barrier, and use a parge coat or airtight paint to seal chasing for services.
- timber frame construction is likely to require an internal racking board – this could be upgraded to an airtight board of similar strength, sealed with tape between boards.
- in a retrofit situation, external wall insulation could include an air barrier that is installed on the building before the insulation layer.

Drawing on a plan or a section in two dimensions with a red pen should be simple, but onsite, an air barrier must be continuous in three dimensions. Key details may need to be illustrated in three dimensions to ensure that sealing requirements are clearly communicated.

Reduce the number and complexity of junctions in the building. For example, a dormer window can add many more junctions to a roof, all of which need to be made airtight. They can also be difficult to insulate well. Hence, opting for a rooflight may be advantageous from an airtightness perspective. More complex architectural shapes can still be added to the external envelope (e.g. overhangs), but as long as they are outside the airtight boundary, then they do not make the airtight layer itself more complex.

Minimise interactions between the air barrier and services. This could be achieved with the use of a service void, for example.

Ensure that the spacing between service penetrations through walls or other elements is sufficient to make effective sealing practical, usually $\geq 100\text{mm}$.

Design for products and systems

Airtightness product supply is relatively new to the UK and new products are being developed and introduced to the market all the time. Ensure awareness of technical developments by checking websites, or attending CPDs offered by suppliers or airtightness specialists.

The five main types of airtightness product are:

- Proprietary airtight board
- Airtight membranes
- Airtight paints and sprays
- Airtightness tapes
- Airtight grommets and other specialist preformed pieces

Some materials used in construction can form part of the air barrier even though they are not marketed as such and these include:

- Concrete cast in situ
- Precast concrete – with care at edges and joints
- Screed³
- Wet plaster > 5mm depth
- Damp proof membranes (polythene sheets) – but likely to need protection from subsequent activities

Unless the proposed air barrier is on the list above, don't assume it is airtight. Products that are commonly used but do not form robust and reliable air barriers are duct tape, gaffa tape, aluminium foil tape, expanding foam, silicon sealant, decorators caulk, dot & dab plasterboard, skim finish, OSB, vinyl, plywood, flooring and masking tape. Airtight products and their properties are summarised in Figures 7 and 8 below.

³ Note that this has been found not to be airtight on some timber-frame PH projects, although the reason for failure is not clear.



Proprietary airtight board

Seal between boards using airtight tape.

Fixings and partial penetrations may need to be sealed with airtight tape depending on board.



Airtight membranes

Seal between membranes using airtight tape.

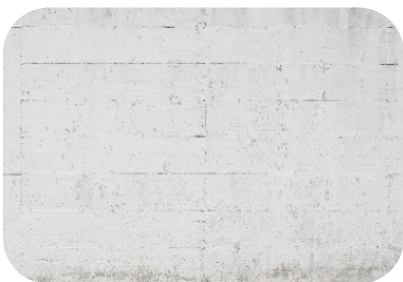
Seal any fixings with airtight tape.



Airtight paints and sprays

Can be compromised by airtightness testing before fully dried.

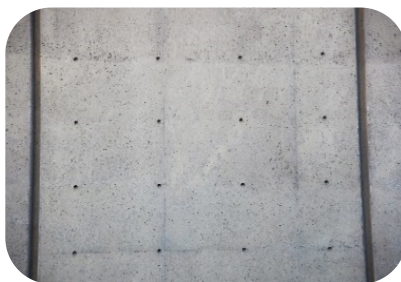
Can be painted, rolled or sprayed on in several coats.



Concrete cast insitu/ICF

Continuous air barrier.

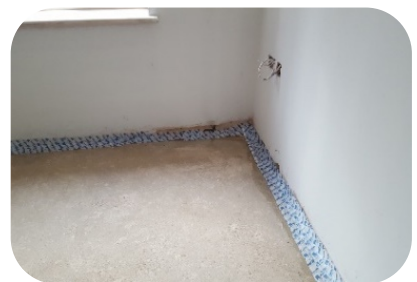
Partial penetrations do not need to be sealed.



Precast concrete panels

Seal notches between panels from below and above.

Partial penetrations do not need to be sealed, but beware of hollow-cores.



Screed

Continuous air barrier.

Partial penetrations do not need to be sealed although thinner screed maybe prone to cracking, so might be advisable.



Wet plaster

Stagger joints in base layer and skim to avoid leakage.

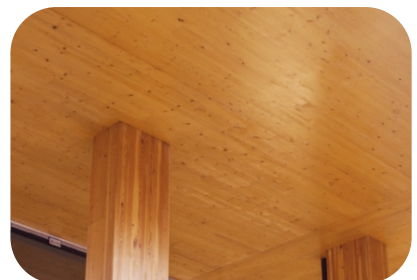
Partial penetrations may not need to be sealed, but could increase risk of cracking.



Damp proof membranes (polythene sheets)

Use airtight tape to seal between sheets.

Seal any fixings with airtight tape.



Cross Laminated Timber

Tape between panels with airtight tape.

Partial penetrations do not need to be sealed.

Figure 7 Summary of airtight materials and their properties





































	Robustness during installation	Ease & speed of installation	Longevity (60 years + air tight)	Cost of material	Notes
Proprietary air tight board					Relatively expensive compared with membranes. Simple to install around tricky details. Pressure activated air tightness tape works well on board. Vapour impermeable. Cost can be mitigated if used to replace racking board.
Air tight membranes	³ 	² 	¹ 	² 	More vulnerable to penetration during installation. Membranes should always have service void in front. Can be compromised by scuffing, with no visible hole but will leak when tested. Whilst material cost is cheaper, installation effort is high which will result in higher labour costs.
Air tight paints and sprays					Weather dependent installation. Need multiple coats to be airtight and each coat requires drying time. New product, high costs, but costs coming down. Good for refurbs and tricky details. Longevity not proven but first entry to market has BBA.
Concrete cast in situ	¹ 	¹ 	¹ 		Very robust. Weather dependent installation. Requires drying time. Commonly used. Inherently airtight, so no additional cost if already part of the design.
Precast concrete panels					Precast panels tend to be airtight. Very fast install, but requires use of crane. (NB Pre-cast planks have large repetitive holes that need to be taken into account when designing the air barrier.)
Screed	² 	¹ 	² 		Screed has high levels of failure due to poor installation around penetrations and edges. Requires drying time, but single pour. Commonly used.
Wet plaster > 5mm depth					Wet plaster must be installed onto a continuous wet edge to a thickness no less than 5mm. Labour intensive, but traditional material. Can crack and fall away, especially when removing or installing wall fixings.
Damp proof membranes (polythene sheets)	² 	¹ 	¹ 	¹ 	Inadequate taping common as it is not usual to tape a DPM with air tightness tape. Commonly used material. Low cost. No additional cost if already part of the design.
Cross Laminated timber					CLT panels are air tight. Very fast install, but requires use of crane. Can be more costly than concrete.

Figure 8 Summary of common air barriers used in construction for robustness, ease and speed of installation, longevity and cost

Getting it right on site



Procurement: Timescales for delivery of airtightness products must be carefully planned and any change request should be managed and agreed with the design team.

Airtightness specialists may be required, or training for existing site staff.

Management processes include the planning and delivery of

- airtightness training,
- change control processes,
- quality control systems (which may include checking, record keeping and risk registers).

It is usually the role of an Airtightness Coordinator to take on responsibility for airtightness management, education and training across the site. It is important to define the role as responsibilities relating to airtightness at an early stage, and communicate this to all site workers.

Training: This may include training on the airtightness strategy and design, installation of airtightness products, airtightness testing or the implementation of airtightness management (see above).

Installation: Only those site workers who have been trained to install airtightness products should work on the air barrier. Work should be checked and signed off by the Airtightness Coordinator or another suitably trained individual. Records should be kept of work on the air barrier before it is covered over.

Installers should make sure they have the correct tools and are working on clean surfaces. They should closely follow manufacturer's instructions for installation of airtight products to get the best outcome.

Testing: Interim testing is essential for any airtight building. The building should be tested at a stage where most of the air barrier is still accessible, so that remedial works can be undertaken. Smoke pens or thermal cameras can be used to aid leak detection. This can be done by an experienced airtightness tester, or it is possible to rent fans and train up site operatives in leak checking, which may allow for more flexibility and save money on larger sites.

The final test is undertaken upon completion of the building or retrofit and in compliance with Passivhaus procedure (ATTMA TSL4) for Passivhaus certification evidence.

Larger buildings

For large or complex projects, or where the design team is inexperienced, it is recommended that an Airtightness Specialist be brought into the design team to review the designs and help develop the airtightness strategy.

In larger buildings it is necessary to consider the interim tests that may be required as construction proceeds. This can be significantly more challenging than the simply defined final acceptance test and may require changes to design and/or program.

The requirements of a project may require different levels of airtightness testing or leakage investigations. Good, simple design should reduce this as far as possible. However, there could still be a need to evaluate individual windows installations, room by room, floor by floor, stair cores, corridors, individual dwellings or part of a site in order to allow separate construction to progress in that location. This could require a separate internal air barrier line being created, which would not have been evaluated at the early design stages and should involve an Airtightness Specialist as well as a potential contractor if possible.

For larger projects the documentation will be much more detailed and comprehensive. Separate documents may be drawn up by specialists for

- onsite airtightness management and process
- roles and responsibilities matrix
- airtightness training plan
- airtightness testing programme

Often airtightness and/or sequencing workshops with the design and construction teams are required on larger projects to ensure the design is well understood by all parties.

Larger sites often have a pre-established management structure and well-rehearsed site processes, into which airtightness management and processes can be integrated. An airtightness coordinator should be employed on all sites, but on larger sites this should not be undertaken by the site manager but the next tier of management.

Partial testing

It may be necessary to undertake partial testing on complex projects. This may involve only testing certain areas to identify the above potential failure points.

Depending upon the fundamental air barrier strategy it could be that co-pressure testing is required for an area or even throughout the site in order to achieve the required effects.

Element testing could be undertaken to give confidence in build methodologies that are to be undertaken for complex junctions or where the installation team are unsure of how to achieve certain work. This could be extended to the delivery and testing of a mock-up.

Localised testing can be used to reduce the requirement to test large sections by demonstrating the effectiveness of elements/details before adjoining airtightness works are carried out, for example, the first window installed.

Case study – new build

St Johns Almshouses are a group of privately rented apartments owned by the charitable trust St Johns Hospital. The larger, three storey Passivhaus block (shown below) comprises 14 of the 18 new apartments. The smaller two storey block sits to the side of the larger block. Both blocks are accessed by external stairwells and lifts.



Figure 9 St Johns Almshouses, Certified Passivhaus flats

Airtightness strategy

The airtightness strategy for this project was originally designed to align with the thermal envelope i.e. around the outside of each block. The construction is masonry cavity wall with solid floor and timber roof. The air barrier consisted of the following materials:

- walls – wet plaster installed directly onto internal blockwork
- roof – airtight board at ceiling level
- floor – airtight damp proof membrane under insulation

Junctions between elements were designed to be joined using membrane and airtightness tape. This relied on membranes being installed prior to the installation of intermediate floors and internal walls.

An early interim test returned results of higher than 3 ACH @ 50 Pa in the smaller block.

Final airtightness test results were 0.50 ACH @ 50 Pa average for all 18 flats with a range of 0.3 to 0.64 ACH @ 50 Pa for individual flats.

Lessons learnt

The airtightness strategy was difficult to achieve onsite in practice which lead to changes in the airtightness strategy. The air barrier was moved to the inside of each flat and a number of lessons were learnt.

- membranes that require installation prior to structural walls or floors need to be clearly sequenced on the drawing as these can be easily missed on site
- membranes installed around heavy concrete intermediate floors are easily damaged upon installation of the floor as it is craned into place (see Figure 26). The detail should ideally be avoided, or the membrane protected by a sacrificial membrane or timber. Sand cement and grouting are more robust airtight materials that could similarly be used at these junctions if sequencing will allow (see Figure 27).
- Taping of the damp proof membrane is not standard practice and requires careful supervision
- Designing an air barrier that envelops a number of flats, each with their own front door in the external envelope, will require co-pressure testing. In this case, up to 5 flats may have to be pressured at the same time. This made testing complex and expensive. However, this cost must be compared with the cost of installing an air barrier between the flats.

A dedicated Airtightness Coordinator who is not the site manager is required. The site manager can't provide the attention and supervision that this role needs.

Case study – retrofit

Elliott Drive is a semi-detached property that was retrofitted to the EnerPHit standard.



Figure 10 Elliot Drive, Certified EnerPHit retrofit

Airtightness strategy

The property was fitted with external wall insulation, solid floor insulation and pitched roof insulation. The main elements of the air barrier are as follows:

- Walls – wet plaster layer on internal surface
- Floor – damp proof membrane under insulation
- Roof – Membrane above rafters at pitched roof level

The junctions between different element of the air barrier were mainly joined using membrane and airtightness tape.

Lessons learnt

The designed airtightness strategy generally worked well, but lessons were still learnt from the project.

- The Airtightness Coordinator role should be undertaken by someone with authority to stop works on the air barrier if necessary.
- Laying the roof membrane above the rafters means that the wall air barrier has to wrap around the roof rafters to join with this (see Figure 21) which is a very tricky detail to install. A better alternative may have been to install airtight board below the rafters and seal the wall air barrier to that. However, airtight board was not available in the UK at the time of this retrofit. Or the air barrier could have been installed in the outside of the building before the external wall insulation. This is risky as the air barrier in the floor can't be joined to the external air barrier, although the ground should be pretty airtight. Low airtightness results have been achieved using this method, but only in larger buildings.
- The air barrier in the floor needs plenty of excess length around the perimeter when it is installed (see Figure 18) so that it can reach up the walls to join with the wet plaster. Once it's installed it's very difficult to extend.

SECTION 2

Airtightness considerations by RIBA stage



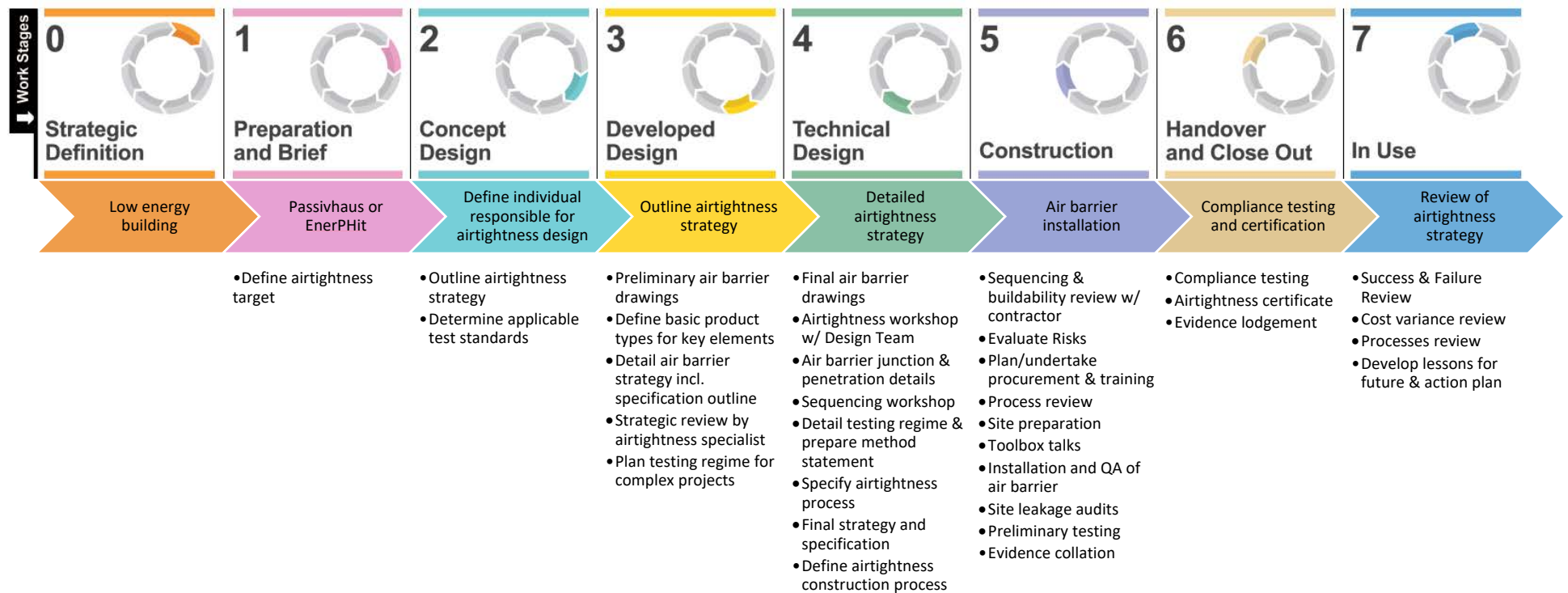


Figure 11 Major tasks relating to airtightness throughout the RIBA stages

1. Preparation and Brief

1.1. Define Airtightness Target

- 1.1.1.1. To ensure success, it is necessary to define the exact airtightness target as early as possible and for all members of the team to understand this. This communication will aid the team in framing decisions regarding construction methodology, structure, contractor etc going forward.
- 1.1.1.2. Passivhaus compliance tests are required in all cases upon completion and should generally have one or more preliminary tests.
- 1.1.1.3. Airtightness targets vary between different building standards, as does the way that airtightness is measured.
- 1.1.1.4. The Passivhaus airtightness target is measured in air changes per hour at an imposed pressure differential of 50 Pascals, units ACH @ 50 Pa. This is different to the standard UK building regulations compliance test (known as ATTMA) which is measured as an air permeability, airflow per square metre of the building's total surface area at 50 Pascals pressure differential, units $\text{m}^3/\text{m}^2.\text{hr}$ @ 50 Pa.
- 1.1.1.5. Passivhaus also has an advisory Air Permeability target of $0.6 \text{ m}^3/\text{m}^2.\text{hr}$ @50 Pa for buildings with a volume of more than 1500 m^3 . It is recommended that, should your building be close to or above this target, the certifier is consulted on the actual target. The target value should be converted into an n50 value for entry into PHPP for evaluation. Such large buildings, and many smaller but complex buildings, need careful airtightness design and planning co-ordination.
- 1.1.1.6. The essential difference is that the Passivhaus methodology is based upon a volumetric calculation (commonly known as n50) of the internal space, whereas the ATTMA test is based upon a total surface area calculation (known as q50).
- 1.1.1.7. The same airtightness test can be used with these calculation methodologies to give both results, providing the building is essentially complete.
- 1.1.1.8. It is essential that teams understand the difference as this can lead to significant construction problems. On more than one occasion a project that was deemed satisfactory at preliminary stage has proven not to be so at final testing and this has been traced to incorrect usage of test criteria at the earlier stage.

2. Concept Design

2.1. Outline Airtightness Strategy

- 2.1.1.1. After setting an airtightness target, the first stage is to decide what are the main elements and products that will form the air barrier, where the air barrier will be located, and when and how many times the building will be tested. This is the outline airtightness strategy.
- 2.1.1.2. This could be a simple sketch representing those main elements and the currently anticipated construction, and forms the basis of the iterative design process for achieving airtightness.

2.2. Design for airtightness testing

- 2.2.1.1. Consideration of the sequencing of the interim and final airtightness testing must form part of the airtightness strategy. It is essential to test the airtightness layer within all elements (walls, roof, floor) while it is still accessible and therefore when remedial sealing works can be carried out if necessary.
- 2.2.1.2. Testing of multiple properties, or units within one building, can be complex if the air barrier has been designed around the whole building. For example, access to flats may be via an external or internal stairwell, possibly also an access balcony or an internal corridor. If flats can only be tested individually, then the airtightness layer should be designed within each flat. If the airtightness layer is around the whole building, and the flats can only be tested individually, then co-pressure testing of two or even more adjacent flats may be required. This is complex and can be difficult, time consuming and costly.

3. Developed Design

3.1. Preliminary Air Barrier Drawings

- 3.1.1.1. At a minimum, architectural drawings should clearly indicate where the air barrier has been designed. This is usually designated by a continuous red line around plans and sections, and there should be a complete set of architectural junction details to show the materials used to make the air barrier continuous around these junctions. The designer must be able to scrutinise their air barrier design in three dimensions as well as two dimensions.

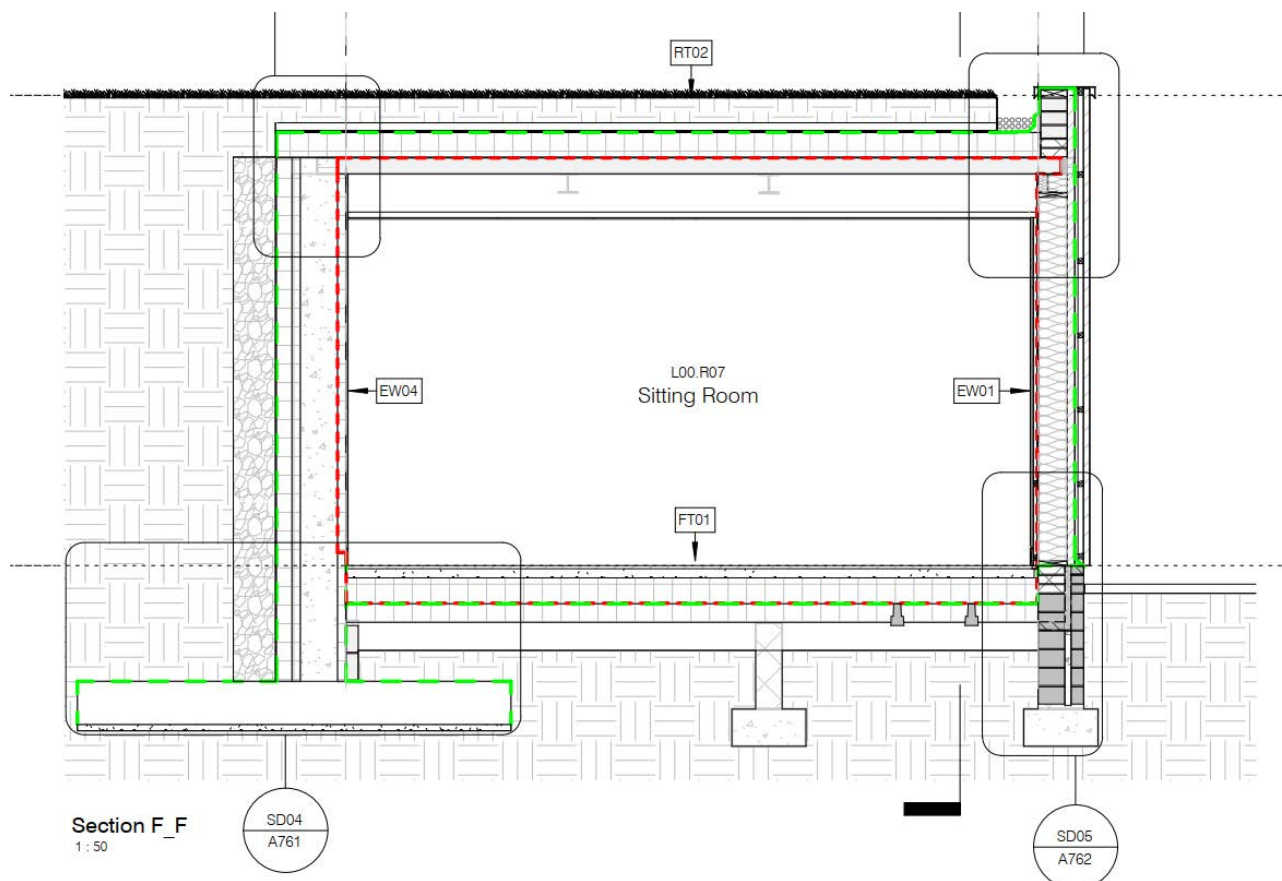


Figure 12 Example air barrier plan section. Red dotted line shows the air barrier.

Define basic types for key elements

3.1.1. Design for products & systems

- 3.1.1.1. Airtightness product supply is relatively new to the UK and new products are being developed and introduced to the market all the time. Ensure awareness of technical developments by checking websites, or attending CPDs offered by suppliers or airtightness specialists.
- 3.1.1.2. The five main types of airtightness product are
- Proprietary airtight board
 - Airtight membranes
 - Airtight paints and sprays
 - Airtightness tapes
 - Airtight grommets and other specialist preformed pieces
- 3.1.1.3. Some materials used in construction can form part of the air barrier even though they are not marketed as such and these include:

- Concrete cast in situ
- Precast concrete – with care at edges and joints
- Screed⁴
- Wet plaster > 5mm depth
- Damp proof membranes (polythene sheets) – but likely to need protection from subsequent activities

Airtight products and their properties are summarised in Figures 7 and 8.

- 3.1.1.4. Unless the proposed air barrier is on the list above, don't assume it is airtight. Products that are commonly used but do not form robust and reliable air barriers are duct tape, gaffa tape, aluminium foil tape, expanded foam, silicon sealant, decorators caulk, dot & dab plasterboard, skim finish, OSB, vinyl, plywood, flooring and masking tape.
- 3.1.1.5. Airtightness product technical support can be very good, and there is now a wide choice of products on the market. Discussing a project with a reputable supplier can be a good starting point. Most suppliers sell through a network of retailers, so although going direct can provide you with technical guidance, you may not be able to buy directly.
- 3.1.1.6. Some building materials are inherently airtight (see para 3.1.1.3), but drawings and specifications must clearly state where they are intended to form the air barrier. The airtightness strategy should offer guidance on how to ensure the products are installed to achieve a good air barrier.

3.1.2. Design for the health of the building fabric

- 3.1.2.1. An internal air barrier prevents warm internal air from moving into the building construction, cooling down and increasing the risk of interstitial condensation. This is different from a vapour control layer that prevents vapour diffusion. Prevention of vapour diffusion and moisture risk management should have their own design strategy, but may have overlapping elements with the airtightness strategy.⁵
- 3.1.2.2. The air barrier must always be installed on the warm side of the insulation. In some cases this can be between the structure and the insulation, such as when external wall insulation is installed in a retrofit. A wind barrier on the outside of the insulation is not an air barrier in this sense, although generally necessary for a Passivhaus project.

3.1.3. Design for simplicity

- 3.1.3.1. Consider the installation of the airtightness selected and the experience and skill set of the contractor. For example,
- for large spans of roof, it may be easier for the contractor to install an airtight board rather than a membrane.
 - many contractors are familiar with a plaster finish on traditional brick and block walls, so this could be the air barrier, and use a parge coat or airtight paint to seal chasing for services.
 - timber frame construction is likely to require an internal racking board. This could be upgraded to an airtight board of similar strength, sealed with tape between boards.
 - in a retrofit situation, external wall insulation could include an air barrier that is installed on the building before the insulation layer.
- 3.1.3.2. Drawing on a plan or a section in two dimensions with a red pen should be simple, but onsite, an air barrier must be continuous in three dimensions. Key details may need to be illustrated in three dimensions to ensure that sealing requirements are clearly communicated.

⁴ Note that this has been found not to be airtight on some timber-frame PH projects, although the reason for failure is not clear.

⁵ See BS 5250:2011+A1:2016 *Code of practice for control of condensation in buildings* for more on the relationship between airtightness and moisture control in buildings.

- 3.1.3.3. Reduce the number and complexity of junctions in the building. For example, a dormer window can add many more junctions to a roof, all of which need to be made airtight. They can also be difficult to insulate well. So opting for a rooflight may be advantageous from an airtightness perspective.
- 3.1.3.4. Minimise interactions between the air barrier and services. This could be achieved with the use of a service void, for example.
- 3.1.3.5. Ensure that the spacing between service penetrations through walls or other elements is sufficient to make effective sealing practical, usually $\geq 100\text{mm}$.

3.2. Detail Air Barrier Strategy including specification outline

3.2.1. Detailed specification and design

- 3.2.1.1. Design information regarding an airtightness strategy should be complete and robust. This will include all the items above such as the air barrier drawings and product types. At detailed design stage the airtightness strategy document is expanded to give a descriptive overview of the air barrier, and at a minimum, should contain information regarding the
 - airtightness target and who is responsible for it,
 - principles of airtightness,
 - airtightness management on site,
 - specific airtightness products for the project,
 - installation of air barriers or where to find installation guidance,
 - airtightness testing regime for the project,
 - airtightness testing protocol,and will reference the architectural drawings showing the air barrier and products used.
- 3.2.1.2. In an NBS the requirements for airtightness will usually appear in section P11. This needs to be considered in preparing the detailed specification.
- 3.2.1.3. For larger projects the documentation will be much more detailed and comprehensive. Separate documents may be drawn up by specialists for
 - onsite airtightness management and process
 - roles and responsibilities matrix
 - airtightness training plan
 - airtightness testing programme

3.3. Large or complex buildings

- 3.3.1.1. For large or complex projects, or where the design team is inexperienced, it is recommended that an Airtightness Specialist be bought into the design team to review the designs and help develop the airtightness strategy.
- 3.3.1.2. In complex buildings it is necessary to consider the multiple variances that could occur with regards to the interim testing of the building as construction proceeds. This can be significantly more challenging than the simply defined final acceptance test and may require changes to design and/or program.
- 3.3.1.3. The requirements of a project may require different levels of airtightness testing or leakage investigations. This may include evaluating individual windows installations, room by room, floor by floor, stair cores, corridors, individual dwellings or part of a site in order to allow separate construction to progress in that location. This often results in a separate internal air barrier line being created, which would not have been evaluated at the early design stages and should involve an Airtightness Specialist as well as a potential contractor if possible.

4. Technical Design

4.1. Final air barrier drawings

- 4.1.1.1. The final air barrier drawings, including details, are iterated and revised as the technical design process proceeds, until a final set are signed off and issued for construction at the end of the Technical Design stage. Normally finalised once the detailed air barrier strategy has been finalised (4.3) and a strategic review has been completed by an airtightness specialist (4.4). Normally GAs prepared with reference to detail drawings for interfaces and penetrations, which are typically separate A3 drawings.
- 4.1.1.2. Ideally the set of red line drawings constitute a controlled document, so that any on-site variations are required to be reviewed for their impact upon the delivery of the airtightness target before they can be implemented.

4.2. Airtightness workshop with design team

- 4.2.1.1. Required for complex or large projects, and particularly advisable on any project if the design team and/or the anticipated contractor lack experience of delivering Passivhaus airtightness on projects of similar scale.
- 4.2.1.2. For smaller projects can be an on-line discussion reviewing key items with the airtightness specialist.
- 4.2.1.3. Will generally include looking for gaps or lack of clarity in the red-line GA drawings, clarifying where simplifications might be feasible and where A3 airtightness detail drawings, some of which might need to be 3-D, are required to ensure effective sealing.
- 4.2.1.4. The airtightness workshop could help prepare a schedule of penetrations, and possibly also include a discussion about future proofing, building in ways for additional penetrations to be installed without compromising airtightness.
- 4.2.1.5. The airtightness workshop must also discuss hold points and the testing regime, to clarify when, where and how the effectiveness of sealing works will be checked before follow-on works which hide the air barrier are permitted to proceed.
- 4.2.1.6. The airtightness workshop is likely to generate a set of action points to be completed by differing members of the design team, and probably also the airtightness specialist, and lead into the preparation of airtightness details that can be issued to installers on site.

4.3. Air barrier junctions and penetration details

- 4.3.1.1. Full guidance for detailed airtightness design at junctions can be found in Section 3. Here we discuss general detailed design issues.
- 4.3.1.2. Airtightness tapes are the most commonly used product for sealing interfaces between two air barriers.
 - Tapes are available for almost any surface and junction, although some tapes require an additional adhesive or primer to be applied prior to application.
 - Tapes are best used for linear joints.
 - Tape specifications should be referenced in all drawings.

4.3.2. Penetrations

- 4.3.2.1. Penetrations through the air barrier should be limited as far as possible.
- 4.3.2.2. A schedule of penetrations, their dimensions, orientation and the applicable sealing method should be provided.
- 4.3.2.3. Sequencing is important since a number of items e.g. EPDM gaskets, may need to be fitted prior

to the installation of the penetration. Ideally, the gasket is fitted loosely around the penetration (e.g. ductwork, plumbing or electrical services) whilst it is being installed, and once the ductwork or other services are fixed in place, then the gasket can be taped back to the air barrier. This prevents any off centre stretching of the gaskets which can cause air leakages.

- 4.3.2.4. Vertical and diagonal wind posts can be difficult to seal in the air barrier and can create awkward penetrations at junctions. Often these can have differential movement to the structure so allowances must be made for this.

4.3.3. Fixings

- 4.3.3.1. Fixtures and fittings such as screws and nails that penetrate the air barrier must be installed with care and follow the specific airtightness recommendations.
- 4.3.3.2. The principle problems experienced with fixings through the airtightness layer, particularly with regard to membranes, is when they are removed and repositioned or replaced. This can significantly damage the membrane and results in it needing to be replaced or repaired. Connecting bolts and screws joining sections of timber frame construction together have also frequently been found to be an airtightness weakness, particularly later in the construction process where the timber has had time to dry and shrink away from the fixings. Requirements for effective sealing of fixings will depend upon the type of air barrier.
- 4.3.3.3. Airtightness membrane: Fixings that penetrate the airtight membrane will require taping. This can be done either prior to the fixing using a specialist butyl or similar tape that will seal around the fixing, or by taping over the fixing once installed with a suitable airtightness tape. This will help seal any holes and avoid tears to the membrane.
- 4.3.3.4. Plaster layer: In general, individual screws and nails that penetrate the airtight plaster layer should not impact on the airtightness of the property if they are firmly installed. If the plaster becomes cracked or chipped in large areas, or the blockwork becomes visible at any point during fixing, then remedial action shall be taken, and the wall may require re-plastering. For especially large screws, or a large number of screws in a small area, silicon sealant should be squirted into the hole before inserting each rawl plug. In existing buildings undergoing refurbishment, any sections of blown plaster (or render) must be removed and a suitable air barrier applied when it is made good.
- 4.3.3.5. Cross Laminated timber, concrete and screed: In general, individual screws and nails that penetrate these air barriers should not impact on the airtightness if they are firmly installed.
- 4.3.3.6. Fixings in airtight boards may need to be treated with airtightness tape depending on where the air barrier is. In some boards, the whole board is airtight and in others, the air barrier is a thin layer on the surface. This can sometimes be damaged by the removal of even temporary taping fixed to the surface.
- 4.3.3.7. A summary of fixings and sealing required for the different plane air barriers is as shown in Figure 6. Typically planed timber is not included in lists of airtight products. However, it is used in airtight window frames, and can be taped to in timber frame construction. It must be noted that timber can move, split, shrink and warp, so any airtightness that relies on timber must be able to accommodate movement in the long term.

4.3.4. Other considerations – vertical shafts

- 4.3.4.1. Vertical shafts, more typically found in commercial buildings, need to be sealed top and bottom and should each have a clear airtightness strategy. Fire regulations may also require intermediate horizontal sealing and it is advisable to take the opportunity and ensure that this is airtight as well as meeting fire stopping requirements. Common shaft types are:
- Stairwells
 - Dry riser (for firefighting)
 - Service risers

- Lift shafts
- Refuse chutes
- Pressurization systems
- Smoke shafts

4.3.5. Other considerations – expansion joints

- 4.3.5.1. Normally expansion joints are sealed for airtightness using flexible airtightness tapes installed such that they have a “bellows” to allow for relative movement between adjoining sections of wall or floor. This tape is then likely to be covered over with a proprietary movement joint.

4.3.6. Other considerations – design for fire separation

- 4.3.6.1. The most common fire protection materials used in UK construction today are plasterboard and firebatt, which is mineral wool coated with intumescent paint. Both of these products are fundamentally airtight and are frequently used to form part of the air barrier for larger non-passivhaus projects. They may be used in Passivhaus projects to form part of the air barrier with care and attention to detail.
- 4.3.6.2. For multi-storey Passivhaus developments fire collars must be fitted as defined by the fire strategy. It is important, however, that the fire collar does not prevent effective air sealing around the pipe or duct.
- 4.3.6.3. It should be noted that many fire products rely on the expansion of intumescent paint, mastic or similar to prevent the spread of smoke and flame and will NOT be airtight under normal conditions.
- 4.3.6.4. In general, any non-expanding fire product can form part of an air barrier.
- 4.3.6.5. For complex buildings, such as blocks of flats, there will be a fire strategy and the airtightness strategy should align very closely with this. Also bear in mind that airtightness testing may be applied to verify different parts of this strategy. As a result, it may be possible to use this as intermediate testing for sign off of certain areas as a project progresses. Any RAMS should include requirements for testing for fire strategy verification.

4.3.7. Other considerations – future-proofing

- 4.3.7.1. Most Passivhaus projects envisage a substantially longer life for the buildings being built than mainstream construction. If designed for 40+ year lifespans, it behoves the design team to incorporate flexibility to allow the modification of the building according to the future needs and desires of occupants.
- 4.3.7.2. Having said this, frequently alterations are made to a project within weeks of completion due to technological developments, such as fibre optic, broadband or satellite services as well as the recent growth of renewable energy installations. Other changes can often occur due to security; installation of fire alarms, security cameras etc.
- 4.3.7.3. Any and all of these potential alterations may require new cables or penetrations through the building envelope. As such design should incorporate the ability to allow for significant expansion that does not compromise the planned air barrier.

4.3.8. Other considerations – thermal bypass

- 4.3.8.1. Thermal bypass is a phenomenon that can be linked with airtightness. Thermal bypass is the movement of air within or through an insulated component such that it reduces the effectiveness of the insulation. To avoid thermal bypass it is essential to prevent air from passing through the building fabric by installing both a robust internal air barrier and an external wind barrier. For more information on designing to avoid thermal bypass, we recommend ‘The impact of thermal bypass’ by Mark Siddall.⁶ This is also a construction stage consideration as the external wind barrier and internal airtightness layer will need to be carefully installed avoiding any gaps.

⁶ ‘The impact of thermal bypass’, Mark Siddall, Green Building Magazine, Summer 2009 (Volume 19 No 1) <https://www.aecb.net/publications/the-impact-of-thermal-bypass/>

4.4. Sequencing workshop

- 4.4.1.1. It is recommended that unless the design team is extremely experienced, then sequencing design is a collaborative process between the design team and the contractor. For large and complex projects, this may require a sequencing workshops where the order of works that deliver the air barrier, including underlying fabric works, is considered.
- 4.4.1.2. Hold points in the construction programme shall be identified to allow for interim or localised airtightness testing or leakage checking. This will verify that the air barrier in every location is satisfactory, before follow-on works that make the air barrier inaccessible are permitted to start.
- 4.4.1.3. The results of the sequencing workshop will feed into the detailed method statement for the testing and may give rise to changes in the project program. Specific hold points may be added onto the relevant air barrier drawings as well as incorporated into the program for the project.

4.5. Detail testing regime

- 4.5.1.1. As the airtightness aspects of the technical design get refined, the requirements for airtightness testing get clarified.
- 4.5.1.2. There will always be a final acceptance test of the completed building. As required for Passivhaus certification, this will comprise both a pressurisation and depressurisation test with the results averaged. For simple buildings a generic risk assessment and method statement (RAMS) will typically suffice, for more complex projects a site-specific RAMS for the airtightness testing will generally be required.
- 4.5.1.3. There will generally be one or two preliminary whole building preliminary airtightness tests. These are often just depressurisation tests, with detailed leakage investigations undertaken as necessary.
- 4.5.1.4. Before the whole building testing, various types of partial airtightness testing and leakage checking may be carried out. This might include testing an individual floor or a separate wing, provided that the construction process enables such sections to be isolated for testing purposes without excessive temporary works.
- 4.5.1.5. Some airtightness sealing can be checked for leakage locally, for example by using some air moving equipment – e.g. a leaf blower or a hair dryer – to apply pressure to a seal. Provided that the other side of the wall/floor/roof is accessible, a second person can verify that they do not feel any airflow pass through the seal in question. Other airtightness sealing can be checked by using a Leakchecker fan applied to a discreet section of the build.
- 4.5.1.6. Interim testing of sections of a larger build, whether of particular elements or of individual floors, wings or other partial volumes, can prove the effectiveness of individual sealing processes or particular operative or contractors, and thereby reduce the risk of experiencing significant leakage problems later in the build.

4.6. Specify airtightness process

- 4.6.1.1. The airtightness process comprises some or all of the items below, and needs to be specified in detail to avoid potential airtightness failures:
 - Training for on-site airtightness champions
 - Practical training in the use of specialised airtightness products such as membranes and tapes
 - Recording of works that generate the air barrier
 - Detailed checking of specific elements of the air barrier, perhaps with localised airflows (typically from a cold hairdryer) or with a Leakchecker fan
 - Site leakage audits – inspecting completed air barrier works and checking for effective sealing works and both a continuous internal air barrier and a continuous external wind-tight layer
 - Generating envelope areas and volumes for buildings or parts thereof as required by the testing to be carried out. Note that for Passivhaus projects the volume must be calculated in

accordance with PHI requirements, on a room-by-room basis, following the guidance provided in Passivedia and the TSL4 standard

- Partial airtightness tests of sections of larger buildings, e.g. one wing of a new school, one floor of a new block of flats
- Since any newbuild Passivhaus project will also need to comply with Building Regulations, it is essential that any requirements for additional or different airtightness testing and certification are identified by considering the standards that apply to the particular project
- Preliminary whole building airtightness testing, typically depressurisation only
- Co-pressure testing of two or more adjacent sections of more complex buildings, if required to validate the airtightness on a multi-unit Passivhaus or EnerPHit project
- Final acceptance airtightness testing of the completed building, both pressurisation and depressurisation testing carried out and the results averaged
- Detailed leakage inspections of sections or whole buildings, as required depending on the results of partial, preliminary or acceptance airtightness testing
- Following completion of the project, undertake a review of the process undertaken to deliver the target airtightness to identify lessons for future projects

4.7. Final Strategy and specification

- 4.7.1.1. Any final changes to the air barrier drawings and the project specifications, resulting from the design team airtightness workshop and the sequencing workshop are made.
- 4.7.1.2. The final project documentation is then prepared and issued for construction, which will comprise:
- Air barrier strategy document
 - Air barrier drawings
 - Air barrier details
 - Specification of products and processes for airtightness delivery
 - Method statement for airtightness testing
 - Project program relating to airtightness, both air barrier installation and airtightness testing
 - QA design statement and requirements for evidence

4.8. Define airtightness construction process

- 4.8.1.1. Delivering the target airtightness on a Passivhaus project is essentially about implementing an air barrier design that has been refined through an iterative process and checked by an airtightness specialist. There will be a final air barrier strategy and a final issue of the air barrier drawings for construction. These will typically include A3 detail drawings of specific interfaces and penetrations.
- 4.8.1.2. There will also be a number of airtightness-related activities included in the program for construction, both the installation of fabric elements and the use of specialist airtightness tapes, membranes and other products that contribute to the overall air barrier. The program should also indicate dates for partial, preliminary and acceptance airtightness testing, and also for site leakage audits if applicable.

5. Construction

5.1. Pre-construction

5.1.1. Sequencing and buildability review

- 5.1.1.1. Once the contractor has been appointed it is of paramount importance that a sequencing and buildability review is undertaken at the earliest possible opportunity.
- 5.1.1.2. The review should be undertaken with the architect, contractor and airtightness specialist at a minimum. If sub-contractors are to be used it would be helpful to include them as well. Including the client can also be beneficial as it will help them understand the complexity to come and understand the importance of any complications that may arise on site and why certain decisions may have to be made in the future.
- 5.1.1.3. This review needs to focus both on the exact sequencing of construction, as previously identified, that is to be agreed with the contractor. Often this will show that different trades will cover certain elements and there are numerous returns by these varying trades. By discussing these interactions early, it is often possible to make changes that reduce risk on site, which in certain cases could be detail simplifications or indeed may seem slightly more complex but allow individual trades to complete their work. This may mean a bit more material use but will lead to simplification in buildability and delivery on site and should as a result lead to cost reductions.

5.1.2. Evaluate Risks

- 5.1.2.1. The products are often new to many contractors and subcontractors, as is the concept of airtightness. It is the role of an Airtightness Coordinator to take on responsibility for management, education and training across the site.
- 5.1.2.2. Larger sites often have a pre-established management structure and well-rehearsed site processes into which airtightness management and processes can be integrated. In medium and small sites, the management structure and processes can be more fluid and it is in these sites that airtightness is often at higher risk of failure.

5.1.3. Plan/undertake procurement – materials

- 5.1.3.1. The contractor must verify that all air barrier drawings are complete and detailed both in specification and sequencing as a number of copies of these we will need to be provided and permanently left available on site.
- 5.1.3.2. The contractor must verify that the detailed specifications are complete and that all products are available within the required timescale.
- 5.1.3.3. Of perhaps most importance in the procurement phase is change management. Should there be a requirement or request to change any air barrier product then this needs to be carefully reviewed by the airtightness specialist or designer. If a change is accepted then this must be issued as a formal notice and edited on drawings.
- 5.1.3.4. Depending upon the scale of the project it may be possible to use airtightness suppliers that offer next day delivery for products, however, it is not certain and this should be carefully planned and considered.
- 5.1.3.5. In order to avoid any potential sequencing issues, it is advisable to set-up timely and robust sourcing of materials. This does not necessarily mean order all items in advance as storage criteria will need to be carefully observed and site storage for a significant period of time may not be suitable.
- 5.1.3.6. Reputable suppliers offer high quality products with little to no batch variations. However, if a timber-based material such as OSB or Cross Laminated timber (CLT) is to be used, the airtightness can vary by batch and design, so it's important to check. However, it should be noted that storage

and exposure on site can have a more significant effect on the end quality. The ability for any timber-based product to remain airtight, or for other airtightness products to adhere to it, is likely to be compromised by a degree of wetting.

5.1.4. Plan/undertake procurement – subcontractors & contracts

- 5.1.4.1. Part of procurement is to ensure the careful recruiting of competent & qualified specialist sub-contractors. Site management may wish to require all airtightness installers to have completed the certified Passivhaus Tradespersons course, or at a minimum to attend site training on airtightness.
- 5.1.4.2. Due to the accuracy required in installing the air barrier it is critical to review the skills and attitude of all sub-contractors that are being put forward for this role. Review previous work and ensure that any skill gaps are identified, and the necessary training is scheduled.
- 5.1.4.3. It is helpful if all subcontractors, not just airtightness specialists, have been made aware of the airtightness target and strategy at the point where the contract is made, prior to working on site, as it may impact on their workload. It is essential that subcontractors are aware of their responsibilities around the air barrier if they are required to report on, repair or install parts of it.
- 5.1.4.4. An Airtightness Specialist, or the Airtightness Champion should review airtightness across all works packages to ensure continuity, and that responsibilities for any of the air barrier installation does not fall between two contracts.

5.1.5. Plan/undertake training

- 5.1.5.1. An airtightness training review should be carried out prior to starting on site. Gaps in knowledge amongst the site management team need to be remedied at this stage. The site management will need to fully understand the requirement for the air barrier to be prioritised and to understand all process that have been put forward for the delivery of the air barrier. This often takes the form of a one day workshop led by an Airtightness Specialist.
- 5.1.5.2. Site management teams will need to be fully trained in operating their QA systems to ensure the satisfactory delivery of airtightness.
- 5.1.5.3. Site management teams may also need to be trained on how to deliver site induction and toolbox talks on airtightness to their subcontractors.
- 5.1.5.4. Airtightness Champions training will need to be delivered to those responsible for managing this directly on site. It should be noted that it is rarely appropriate for this to be the site manager, due to excessive conflicting demands on the site manager's time. Commonly, the next level down of management on site should take the lead in managing the delivery of airtightness. However, on small sites, it may be unavoidable.

5.1.6. Process review

- 5.1.6.1. Delivering an airtight building relies heavily upon careful management and in order to do this a number of processes are required. The basic outline of these have been highlighted in the above text. In more complex or larger buildings there would normally be significantly more, incorporating such items as sequencing quality checklists, site inspection checklists, site inspection reports etc.
- 5.1.6.2. The core processes that need to be reviewed on any project include Quality Control, record keeping and the risk register. These are all airtight specific items which need to be evaluated independently and dependent upon the scale of the project incorporated into other site processes.
- 5.1.6.3. All roles and responsibilities across the different works need to be clarified. It is regularly found that the interface between trades needs to be clarified to deliver good airtightness, e.g. who is responsible for remedial sealing after core drill through parged masonry to install ductwork.
- 5.1.6.4. If there are site/project specific checklists to be developed they need to be finalised at this point (e.g. sequencing, inspection etc).

5.1.7. Site preparation – site culture

- 5.1.7.1. One of the most important aspect of delivering a total airtight air barrier on site is the ability to deal with the inevitable errors that will occur. The vast majority of construction in the UK rely upon trades delivering an end product that looks right within a certain timescale. As a result, some construction is not best practice when examined closely as mistakes are often covered over. This is not suitable in any form for Passivhaus.
- 5.1.7.2. If an error occurs it is necessary that it is reported quickly and efficiently so that the correct party can resolve this. The best way of encouraging this is to ensure that the Passivhaus site employs a 'NO BLAME' culture. For this to work it must be led by the site management. With this policy in place all items will be reported and can be dealt with accordingly by the person best trained to deal with it.
- 5.1.7.3. This policy must form part of the toolbox talks and all site workers fully understand that everything must be reported and that they will not be blamed for accidents as these happen on every site. However, additional checking, particularly of recent starters on site, is advisable to check that this policy is working effectively.

5.1.8. Site preparation – risk register

- 5.1.8.1. The risk register outlines those airtight specific risks that are expected at each stage of development of the air barrier.
- 5.1.8.2. It should ensure that there is adequate risk associated with every interim test and identification of hold points for signing off risk from earlier stages.
- 5.1.8.3. This will aid site management, the design team and any independent inspectors (for Certification or otherwise) to evaluate when the best times will be to attend for site inspections.

5.1.9. Site preparation – training

- 5.1.9.1. All staff and sub-contractors working on site must complete a site induction that emphasises the airtightness strategy, airtightness target, permissible working areas, airtightness signage understanding and site reporting procedures.
- 5.1.9.2. Frequently contractors and sub-contractors will be working with products they have not used before for delivering airtightness. Training will be required to fully understand how these are installed and applied. This may cover items such as surface preparation, application limitations such as low temperature, high humidity etc. Indication and usage of correct tools and techniques.
- 5.1.9.3. This training of site operators must not be confused with the above training which is specific to site management unless they are the same personnel.

5.1.10. Site preparation – storage

- 5.1.10.1. Upon delivery to site it may be necessary to log the deliveries of air barrier products for Passivhaus quality assurance.
- 5.1.10.2. Once the airtightness products have been carefully specified and delivered to site, it is necessary to be aware of their storage requirements. Potential temperature fluctuations, humidity fluctuations, UV exposure and dust ingress may need to be avoided. Certain products may have a shelf life for application.

5.1.11. Site preparation – displays

- 5.1.11.1. On PH projects it is advisable to create various displays relating to airtightness. These are commonly located in the site meeting room (for inductions and training purposes) and in the site canteen (to provide an on-going reference for operatives). On larger PH projects these will also be placed at strategic points around site with specific detail drawings at the most challenging locations to warn all site workers.

- 5.1.11.2. There will typically be a display relating to airtightness generally, covering the PH target, often the air barrier strategy, the NO BLAME culture, and the identity of Airtightness Champions and other key staff (ideally with photographs) to whom airtightness issues or problems should be reported.
- 5.1.11.3. A second display would normally feature examples of all the airtightness products to be used on site and information on their installation e.g. the sizes of different grommets and what they are to be used for, or which tape widths for different locations. Any foam or other expanding product (e.g. Compriband) should be illustrated and where it may be used strictly defined to avoid indiscriminate and often ineffective application wherever a sealing operative is uncertain as to the correct approach. Examples of any other specialised airtightness products should be provided e.g. joist boots, and how and when they are to be used defined. Limitations on the usage of products, commonly minimum and maximum temperatures and/or humidities, are also detailed.
- 5.1.11.4. A third board is strongly advised to reinforce the crucial requirement of surface preparation before any form of air barrier bonding product is used, whether this is a tape, paint, primer or other form of adhesive product. This could also reinforce the benefits of general site cleanliness.
- 5.1.11.5. Finally, it is recommended that a board that promotes feedback from site operative regarding the air barrier is placed in a prominent position on the site. This board may also help maintain the site processes relating to airtightness. For example, it could host a clipboard for site operative to sign if they have worked on the air barrier, and in which locations, which then needs to be co-signed by the Airtightness Coordinator to show that it has been checked.

5.2. Construction

5.2.1. Toolbox talks for installers – prep, product introduction and training

- 5.2.1.1. It is recommended that any new contractors or subcontractors that have not been on site before are briefed on Passivhaus, and more specifically, airtight issues. Toolbox talks, at a minimum, should cover the following information related to airtightness and should ideally be delivered by an Airtightness Champion;
- Basic principles of airtightness
 - Airtightness target
 - Airtightness strategy
 - Management processes on site
 - What is and is not an air barrier
 - Storage of materials
 - Reporting procedures

5.2.2. Installation and QA of air barrier

- 5.2.2.1. This section is only an outline for installing air barrier products. Installation of air barriers should be undertaken by trained and competent individuals with effective oversight.
- 5.2.2.2. Airtightness tapes generally use a pure acrylic glue that is pressure activated. This means that a press-fix tool (often supplied by the tape manufacturers) is an essential part of the installation process.⁷
- 5.2.2.3. Careful consideration of the environmental conditions for application of tapes as well as other product specific installation instructions must be observed as they can fundamentally compromise the effectiveness of the products.

⁷ What makes an adhesive tape stick... and stay stuck! Fintan Wallace, Ecological building systems, 2018
<https://www.ecologicalbuildingsystems.com/post/what-makes-adhesive-tape-stick-and-stay-stuck>
<https://www.ecologicalbuildingsystems.com/post/wetness-airtightness-what-makes-adhesive-tape-stick-and-stay-stuck-part-2>

- 5.2.2.4. Tapes must not be stretched or pulled taught before application i.e. they should be applied from one side only and not held out and then stuck on before using a press-fix tool. See image for correct application.

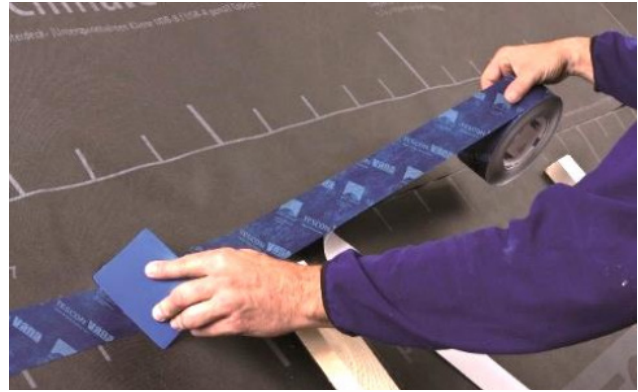


Figure 13 Correct installation of an airtightness tape using a press-fix tool

- 5.2.2.5. Preparation of surfaces is essential for good application of airtightness tapes, glues and sealants. Surfaces must be clean and dry or the tape will stick to the debris and not the surface as shown in Figure 14.



Figure 14 Photo of airtight tape that has been applied to an unprepared surface

- 5.2.2.6. Door thresholds will need to be well protected onsite, especially if there is an exposed air barrier.

- 5.2.2.7. Taping into corners must be to right angles, especially at window reveals where the reveal finish must be installed onto the air barrier. It is generally safer to create corner tapes first and then install tape to that.



Figure 15 Airtightness tape applied to a window reveal that closely follows the contours of the reveal

- 5.2.2.8. Tape rolls should at no point be permitted to rest on a surface unless all edges are protected. Debris adhering to edges can cause the tape to fail to adhere properly to the correct surfaces and lead to failure of the air barrier.
- 5.2.2.9. Reveals for doors and windows can be locally checked using a hand held air blower (or similar) or ensuring that the taping is still exposed when interim airtightness tests are undertaken.

- 5.2.2.10. Ensure ironmongery for windows and doors has been installed prior to airtightness test so that they can be sealed shut.
- 5.2.2.11. More generally, Passivhaus projects need to pay attention to the possibility of movement, since that can very commonly compromise the airtightness layer, especially in timber frame buildings where shrinkage and cracking due to the drying out of wood beams, columns and joists is normal in the UK. This could perhaps be mitigated by more extensive efforts on site to protect timbers from rain or other moisture, however it is likely that such problems will still occur in UK Passivhaus projects. Therefore, applying tape between sections of timber, including airtight OSB or SIPs panels, should take account of the likelihood of movement and hence not be applied fully taut. The corners of window and door openings are particularly vulnerable, hence the development of “rabbit-ears”, taping in the corners of openings as a technique to minimise the failure of airtightness tapes due to shrinkage of timber elements. This is also why decorators caulk should never be used on Passivhaus projects, and even the use of silicone mastics should never be part of the airtightness layer.

5.2.3. Quality Assurance

- 5.2.3.1. On small sites this is generally carried out as part of other duties by the site manager and often the site owner.
- 5.2.3.2. On larger sites this should not be undertaken by the site manager but the next tier of management.
- 5.2.3.3. Site QA can take the form of site walkarounds with torches, site leakage audits and preliminary testing in addition to those procedure verifications that have been put in at the earlier stages of design.
- 5.2.3.4. Additional responsibilities undertaken must be for managing storage, signing off and retention of delivery notes, reviewing sign off and installation photos and accepting responsibility for completion of hold points.
- 5.2.3.5. They must also verify the capability of all installers and identify any training requirements.

5.2.4. Site leakage audits

- 5.2.4.1. A site leakage audit is generally a walk around with an airtightness specialist or an airtightness champion, and possibly includes a member of the airtesting organisation. The purpose of the audit is to identify areas where airtightness work is incomplete or does not meet a sufficiently high standard and/or any failures in process.
- 5.2.4.2. The key objective is to avoid unnecessary failing of or failures during preliminary testing. This should also be used as a verification of success/failure of sequencing and buildability of the air barrier.
- 5.2.4.3. On larger projects the site leakage audit can also serve to check and validate the proposed methodology for airtightness testing.

5.2.5. Preliminary testing on simple projects

- 5.2.5.1. On simple projects this is generally a depressurisation test performed in order to identify weaknesses in the air barrier. This occurs once the general air barrier installation is complete and still accessible and before services are fully installed.
- 5.2.5.2. Preliminary airtightness testing requires a competent airtightness tester and investigator who should provide you with a full photographic leakage report.
- 5.2.5.3. Should significant leaks be found then temporary taping may be used to identify the scale of these leaks through comparative testing. This will all be detailed in the same report.
- 5.2.5.4. On rare occasions it may be needed to pressurise the building in order to demonstrate a point of failure. This will be instigated by the airtightness investigator. The test will be able to identify a current state of airtightness for the project.

5.2.6. Preliminary testing on large/complex projects

- 5.2.6.1. In addition to the above it may be necessary to undertake partial testing on complex projects. This may involve only testing certain areas to identify the above potential failure points.
- 5.2.6.2. Depending upon the fundamental air barrier strategy it could be that co-pressure testing is required for an area or even throughout the site in order to achieve the required effects.
- 5.2.6.3. Element testing could be undertaken to give confidence in build methodologies that are to be undertaken for complex junctions or where the installation team are unsure of how to achieve certain work. This could be extended to the delivery and testing of a mock-up.
- 5.2.6.4. Localised testing can be used to demonstrate effectiveness of elements before adjoining airtightness works are carried out e.g. the first window installed.
- 5.2.6.5. It is of importance that larger and more complex projects identify key areas of the airtightness testing strategy during the design process. This should be identified through the design review with the airtightness specialist as highlighted in Section 4.5.

5.2.7. Evidence collation – recording deliveries and cross checking

- 5.2.7.1. Someone on site should be made responsible for recording deliveries of airtightness products and cross-checking against the design. This is usually the Airtightness Coordinator.

5.2.8. Evidence collation – photo records

- 5.2.8.1. Although keeping photo records of airtightness material deliveries may seem trivial, it does keep the on-site team diligent, and provides future evidence should any element of the airtightness application be disputed further down the line.
- 5.2.8.2. Photo evidence for all junction details should be undertaken and stored in a referenced manner.
- 5.2.8.3. Material storage facilities should be photographed to demonstrate correct product use.

5.2.9. Evidence collation – training records

- 5.2.9.1. Depending upon the complexity of the site, full records should be retained to indicate who has been trained and to which levels.
- 5.2.9.2. This will identify which personnel are permitted to work on which areas of air barrier installation.

6. Handover and Close Out

6.1. Compliance Testing

- 6.1.1.1. This is the acceptance test required for Passivhaus certification. This is undertaken when the building is complete from an airtightness standpoint, and no significant temporary sealing, other than that carried out to eliminate the MVHR system, is permitted. Both pressurisation and depressurisation tests are carried out and the results averaged.
- 6.1.1.2. Airtightness testing for UK Passivhaus projects is carried out in conformance with the following ATTMA standards:
- TSL1 (2016) & TSL4 (2018) for domestic properties
 - TSL2 (2011) & TSL4 (2018) for non-domestic properties
- 6.1.1.3. Note that these standards are all currently being revised by ATTMA, alongside the changes to Part F and Part L of the Building Regulations.
- 6.1.1.4. A new standard 'TSL3' is also under development. This will be for the airtightness testing of complex buildings, which may well include larger PH projects which are modelled in PHPP on a block basis.
- 6.1.1.5. Those witnessing or reviewing acceptance airtightness testing on Passivhaus projects must ensure that:
- the airtightness tester is reliably competent
 - the test equipment has current calibration certificates
 - the existing pressure differential, measured both before and after each test, does not exceed the maximum values specified in the ATTMA standards (i.e. the absolute value of the internal to external pressure difference must not exceed 5 Pascals)
 - the data set collected meets ATTMA requirements (i.e. at least one reading at an imposed pressure differential of ≥ 55 Pa, a minimum of 7 readings, a minimum range between the highest and lowest readings taken of ≥ 25 Pa)
 - the airtightness tester validates the volume and envelope calculations with on-site measurements or that a specific survey has been commissioned to verify as-built measurements

6.2. Airtightness Certificate

- 6.2.1.1. Organisations which undertake air testing will generally provide branded air leakage certificates, which are then submitted to the Passivhaus certifying body and the Building Control body.
- 6.2.1.2. As the testing requirements for Passivhaus differ from Building Regulations, the airtightness certificate must document both the test results (air permeability, air change rate, airflow, all at 50 Pascals) and the supporting evidence that must be assessed to confirm the validity of the testing. This consists of:
- the location and date of the test
 - the name, affiliation and registration of the test engineer
 - a unique certificate reference number
 - the average data consistency (the r^2 value)
 - the average slope for the graphing of the pressurisation and depressurisation data sets
 - the envelope area and volume of the building tested, and who prepared them
 - the existing pressure differential before and after the testing
 - the barometric pressure at the time of testing
 - the internal temperature before and after the testing
 - the average external temperature during the testing
 - details of the complete test report where full calibration information and records of test measurements are provided, together with the derivation of envelope area and volume
 - any deviations from the approved test methodologies and relevant ATTMA standards

6.3. Evidence lodgement

- 6.3.1.1. Acceptance airtightness testing on Passivhaus projects shall be lodged online with a registered competent persons scheme. Currently there are two recognised schemes operating in the UK which support Passivhaus standards of air testing- ATTMA (www.bcta.group/attma) and iATs (iats-uk.org). The scheme's lodgement site will also provide a location to which the volume and envelope calculations as well as the final test report can be uploaded for future reference purposes.
- 6.3.1.2. The full airtightness test certificate as well as calibration certificates and envelope and volume calculations should be provided to the Passivhaus certifier.

7. In Use

7.1. Success and failure review

- 7.1.1.1. Achieving Passivhaus levels of airtightness is one the biggest risks associated with Passivhaus design and construction. Much of the guidance so far has been to reduce or manage that risk. Inevitably there will be some successes and some failures, so it is important to take stock and review the whole project, as is good practice in any construction project.
- 7.1.1.2. Review which details typically leaked less and which leaked more, this information can be found in any good interim leakage test report, along with relevant photos. Analyse whether the design, or construction of that detail could have been improved, and perhaps brainstorm ideas of how to do it better next time.

7.2. Cost variance review

- 7.2.1.1. It is essential to review cost variance in airtightness for Passivhaus projects. Airtightness is often perceived as being one of the highest additional costs of Passivhaus since the target is far more stringent than what is typically expected in the UK. It is important to collect the facts from your own project and others.
- 7.2.1.2. Remedial airtightness work can quickly take a project over budget. Review if this was a consequence of design decisions or poor implementation on site. Could more budget have been spent on a different, but lower risk design, or on employing a specialist airtightness consultant to review the design, or on improving site management procedures? The balance of these additional costs to the cost of remedial work can help inform future decisions.
- 7.2.1.3. Third party air leakage testing can also become expensive if repeated visits are required after remedial work has taken place. Review the cost of hiring a fan and receiving some basic training in order to be able to undertake air leakage detection by the site staff.
- 7.2.1.4. If co-pressure testing creates complex set-ups for airtightness testing, then review the extra cost of installing air barriers in each dwelling or section of the building to avoid co-pressure testing. Sometimes, these decisions are made at the start of the project, but the cost information is not accurate enough to be helpful.

7.3. Process review

- 7.3.1.1. Reviewing how airtightness was managed throughout the design and construction process can uncover weaknesses, or gaps. The impact of any management deficiencies should be analysed. There should be a clear line of responsibility throughout the project for airtightness.
- 7.3.1.2. It is particularly important to review all the site management processes related to airtightness. Discuss whether each one worked for the site staff, subcontractors and design team, and if they helped to achieve the end goal of airtightness.

7.4. Develop lessons for future and action plan

- 7.4.1.1. Passivhaus buildings don't require retesting to maintain their certification, and if the correct airtightness products have been installed according to manufacturer's instructions, then they should maintain their airtightness. Timber frames buildings can become leakier over time due to movement in the building structure as the timber dries out.
- 7.4.1.2. Make record of all the above reviews, with clear learning points, and tips for future projects. These reviews can reduce risks and therefore costs of future Passivhaus projects. Ensure that they are shared with all members of the project team.

SECTION 3

Detailed airtightness design



Penetrations

Installation of electrical sockets and similar fixings in chased blockwork will require sealing with a parge coat or airtight paint as shown in Figure 16.



Figure 16 Chasing in blockwork for electrical switches and wiring, treated with an airtight paint that paints on blue and dries black when airtight

Typically, timber, steel and concrete frame buildings will have a service void on the walls and ceilings and the air barrier will be situated at the back of the service void where there will be minimal penetrations.

Wall to floor junctions

If using wet plaster to deliver airtightness on the walls, this needs to reach to floor level to avoid an exposed strip behind skirting, which is not normal practice, so this must be specified.

Wall to floor junctions where the screed is the air barrier, may be as shown in Figure 17. In this situation, an insulated perimeter upstand is typically included in the floor build-up to allow for expansion. In such instances, the airtightness tape specified must be sufficiently wide and sufficiently robust to cover the insulation and join the screed to the wall. It is also essential that the tape is fitted tight into the corner between the wall and the floor, otherwise the subsequent installation of skirting boards is likely to tear the perimeter airtightness tape unless there is a service void.

All penetrations will need to be sealed to the top of the screed layer once the screed is installed.

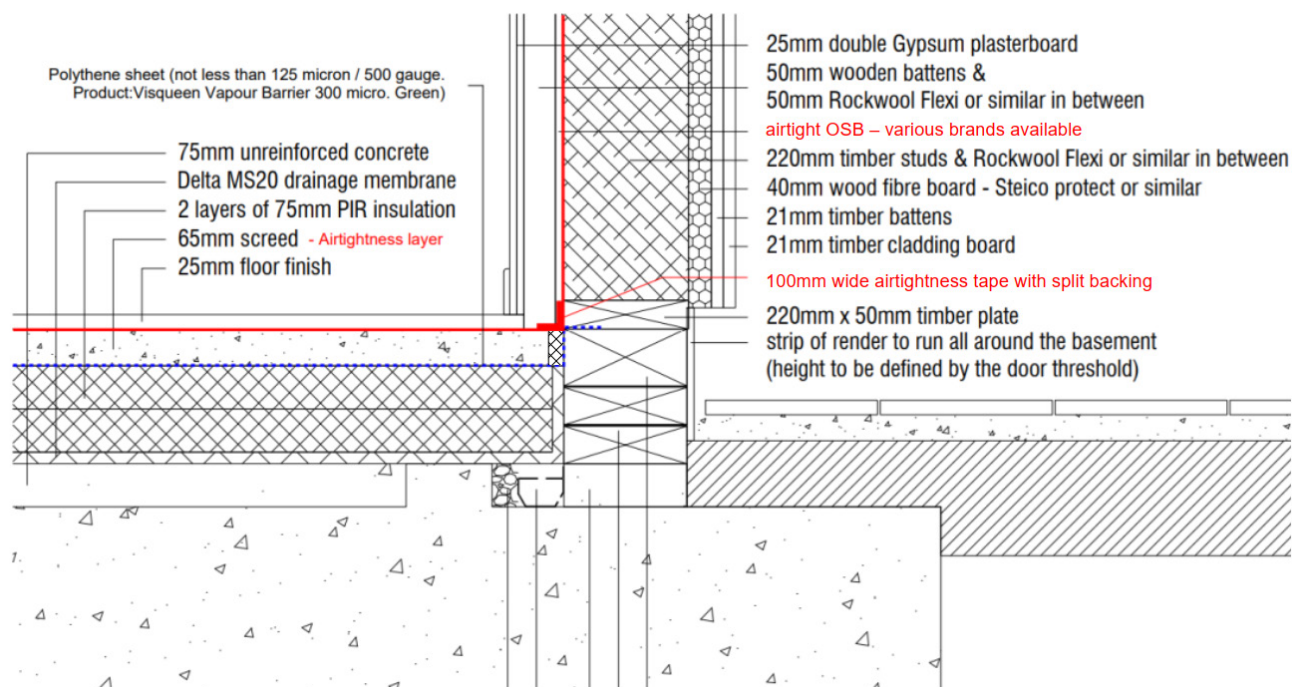


Figure 17 Basement wall to floor junction with air barrier.

Wall to floor junctions where the damp proof membrane (DPM) is the air barrier may be as shown in Figure 18. The DPM must extend up the wall past the floor build up to be taped to the air barrier on the wall. The DPM must lie flat against the wall in order for it to be effectively taped. This can be more difficult to achieve at any wall to wall junctions where hospital corner folds may be used. The thickness of the DPM at design stage can be critical to the success of this detail. No thicker than 1000 gauge DPM is recommended when folding is required in corners. Pre-formed internal and external corners (see Figure 19) are available from DPM manufacturers and can avoid the problems commonly experienced with folded corners.



Figure 18 Damp Proof Membrane as air barrier, to be taped up internal walls and joined to plaster layer behind skirting

Using the DPM as the air barrier is high risk since it is often covered prior to the first interim airtightness test when the rest of the air barrier is complete. There have been occasions when screed has had to be removed to undertake remedial work on the air barrier in the floor. It is essential to ensure that all tapes are compatible with the DPM and other materials. Penetrations must be sealed to the DPM prior to installation of floor coverings.

Contractors will not be familiar with taping DPM junctions between sheets with airtightness tape, and therefore this must be included in the specification and drawings.

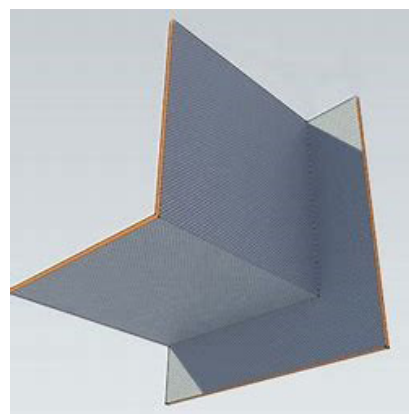


Figure 19
Preformed corner air barrier product

If carrying out preliminary airtightness testing with a DPM or other membrane as the airtightness layer in the floor, depressurisation testing will generally cause this to billow up into the test space, even with insulation fitted on top. This can result in significant damage to the membrane. Hence it is generally advisable to initially carry out a pressurisation test, even though this makes leakage identification very difficult. Once the airtightness value has been established, depressurisation testing can be carried out for leakage identification purposes, although weighting down of the membrane and insulation is advisable before pressure is applied.

Wall to roof junctions

Wall to roof junctions are usually lower risk as they can be simply a case of taping the wall air barrier to the ceiling air barrier as shown in Figure 20.

Where a dropped ceiling is designed, the air barrier must be installed on the wall prior to the ceiling being installed. In the case of wet plaster it is not usual to plaster the walls before installation of the dropped ceiling, therefore this must be explicit in the airtightness strategy specification and drawings.

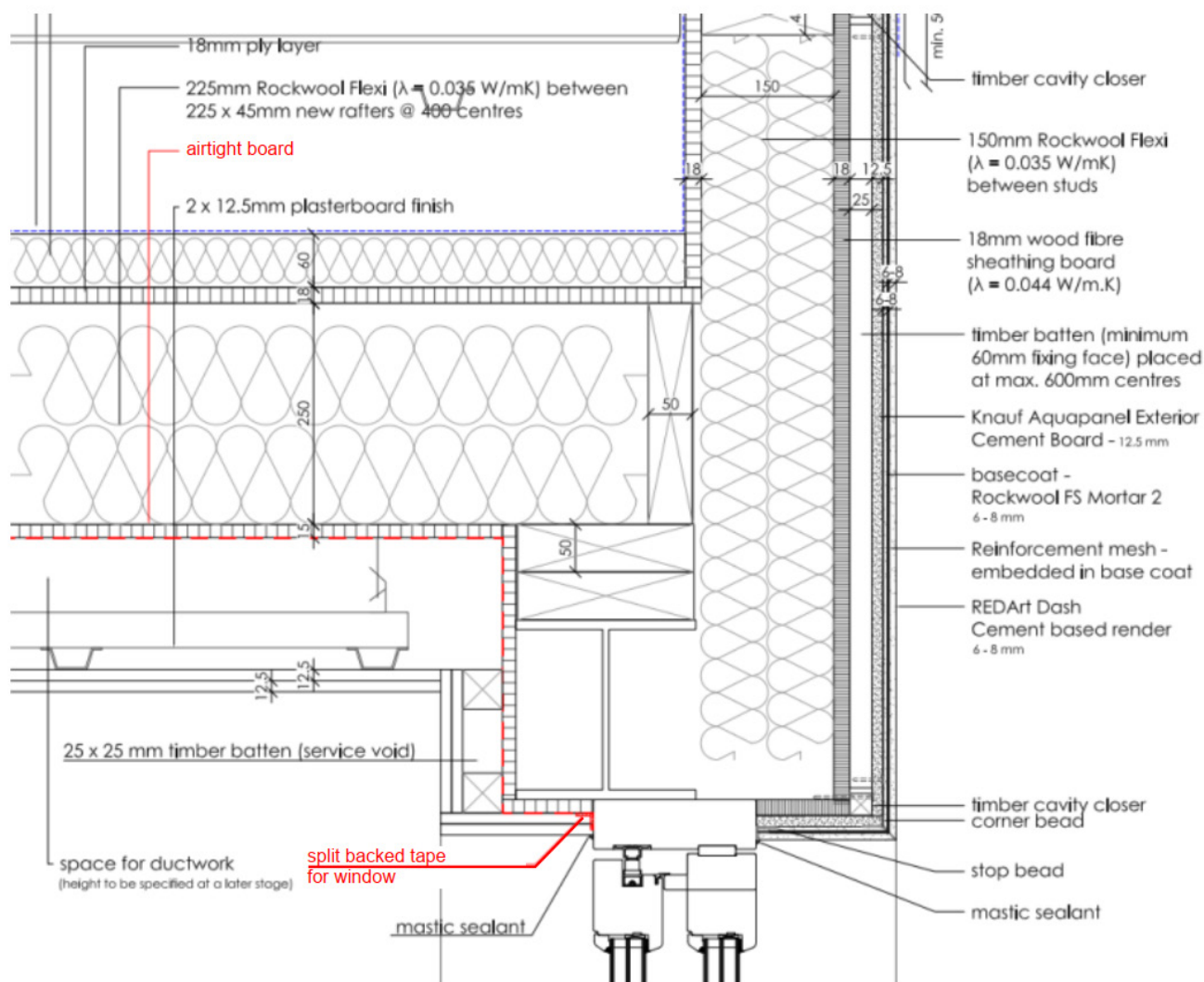


Figure 20 Wall to roof junction with window head

Where the air barrier is installed on top of the joists it must be well sealed around each joist in order to connect with the internal air barrier on the walls. This is a difficult detail and is more common in retrofits as shown in the Figure 21. This can be made more robust by using airtight board instead of membrane.



Figure 21 Photo of airtight membrane connecting internal air barrier to membrane over the roof joists

Window and door junctions

In order to ensure airtightness in windows and doors, they should achieve a Class 4 or above rating according to classification BS EN 12207 and test method as described in BS EN 1026⁸. If there is no test, then look for double or triple airtightness seals on the profile, or ask the manufacturer if they have any examples where their products have been used in a Passivhaus or similar.

Windows and doors must be robustly sealed to the air barrier at the head, jambs and threshold. Drawings should be supplied that show all these junctions. An example of a window jamb to wall junction detail is shown in Figure 22.

Tapes specified for windows and doors should be simple to manipulate into corners and ideally have a split backing to allow for ease of installation. Sealing operatives should practice the creating of pre-formed tape corners for such installations, and these should be applied before the longer straight lengths of tape around the bulk of the opening.

Sequencing is important for window and door junctions. The order of the window or door installation, the fitting of the air barrier in the reveals of the opening, the connection of tapes to the fabric, the windows and any membranes and installation of cills (see Figure 23), and the finishing of surfaces in the reveal are critical.

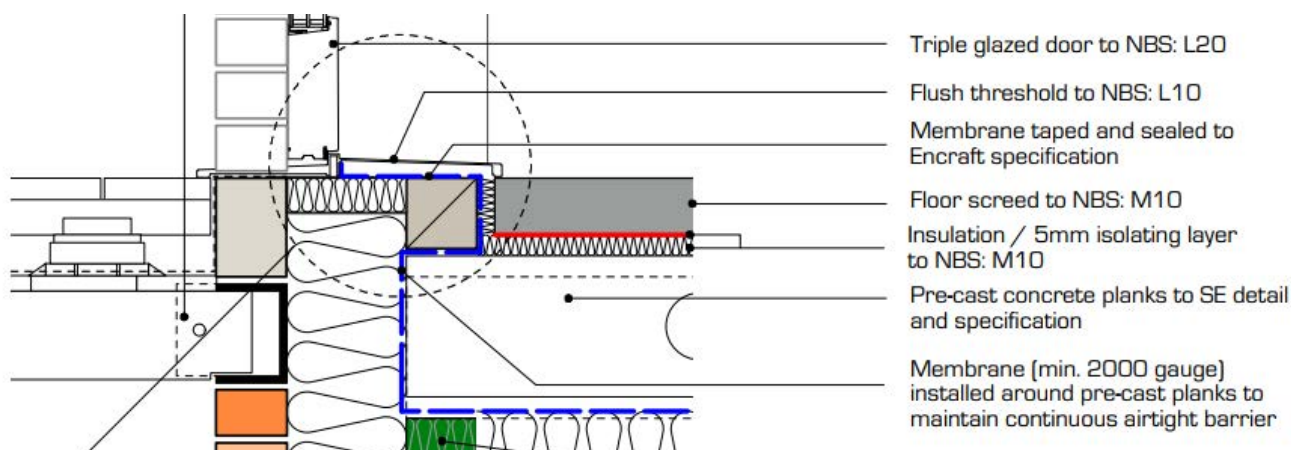


Figure 22 Window installation with air barrier.

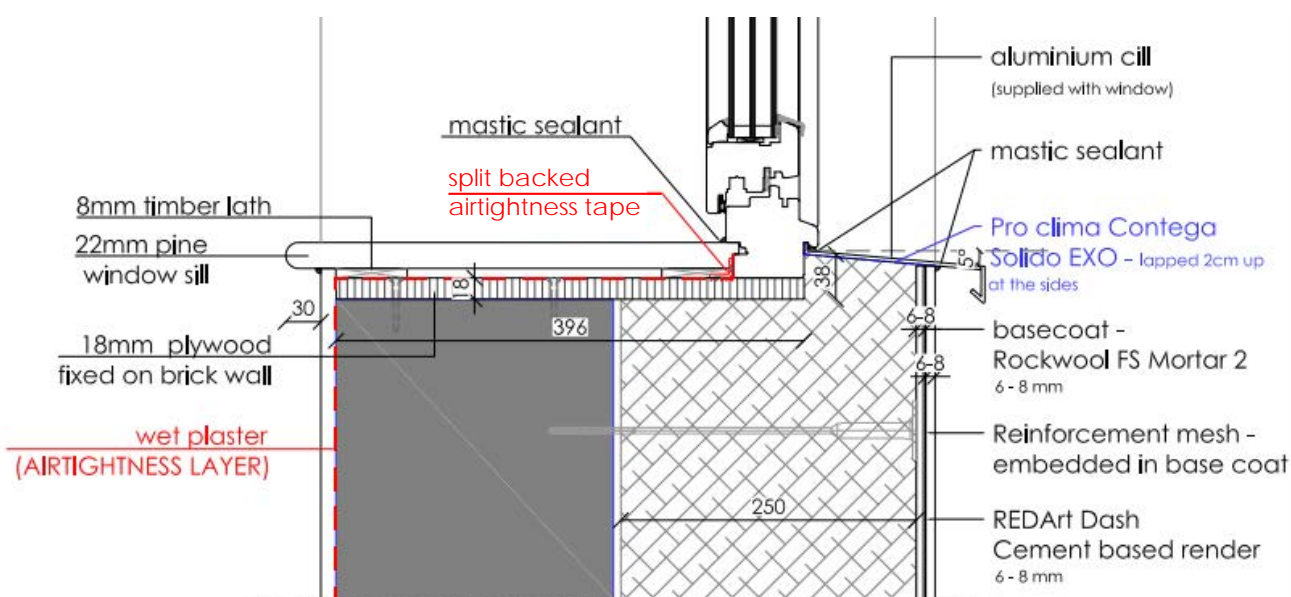


Figure 23 Window cill installation with air barrier.

⁸ Class 3 has been known to pass the Passivhaus airtightness test, but it is advisable to go for Class 4.

Door thresholds are a common weak point, with level access requirements often making delivering effective airtightness more difficult. Hollow aluminium door thresholds often need special attention to prevent air leakage bypassing the airtightness around the opening.

Passivhaus bi-fold and sliding doors are available, however they have proved problematic onsite in achieving the airtightness target, particularly larger doors.

Using a well-insulated structural mullion to break up large expanses of openable glazed areas, can be a good way of reducing the risk of air leakage. .

Electrically controlled openable windows and doors, that may be required for fire safety or high-level ventilation, for example, may increase the risk of air leakage as they might not be capable of sealing the otherwise airtight opening. A specialist airtightness consultant will be able to advise the impact of these in our airtightness design.

Specialist doors such as security doors or large access doors, can be tested at the factory using a hand held air blower before it may be specified. Sometimes it is possible for manufacturers to add additional seals where no airtight product is available. A specialist airtightness consultant will be able to advise the impact of these in our airtightness design.

In large non-domestic projects, less airtight doors e.g. rotating doors and automatic doors will have a lower impact on the overall airtightness of the building, so may be feasible. A specialist airtightness consultant will be able to advise the impact of these in our airtightness design.

Intermediate floor junctions

An internal air barrier must be continuous across an intermediate floor. Where intermediate floors abut internal walls, the design team should consider how the floor is to be fixed to the wall since this will almost always result in penetration of the air barrier. If possible, the air barrier should remain accessible such that remedial work can be undertaken if leaks are detected in this area. In this case, the air barrier will continue in a vertical line and wrap around any joists or fixings used for the intermediate floor as shown in a Passivhaus retrofit project (EnerPHit) in Figure 24.



Figure 24 Intermediate floor to wall junction. Air barrier is wet plaster with membrane and airtightness tape around the joists.

A fundamental design simplification that makes Passivhaus airtightness easier to achieve is to avoid installing joists into the wall. Fitting a perimeter beam, from which joist hangers support the intermediate floor, is a far more robust airtightness detail.

In timber frame constructions shaped OSB sections as shown in Figure 25 can be prepared and fitted around joists to provide a robust backing for taping around the joists.

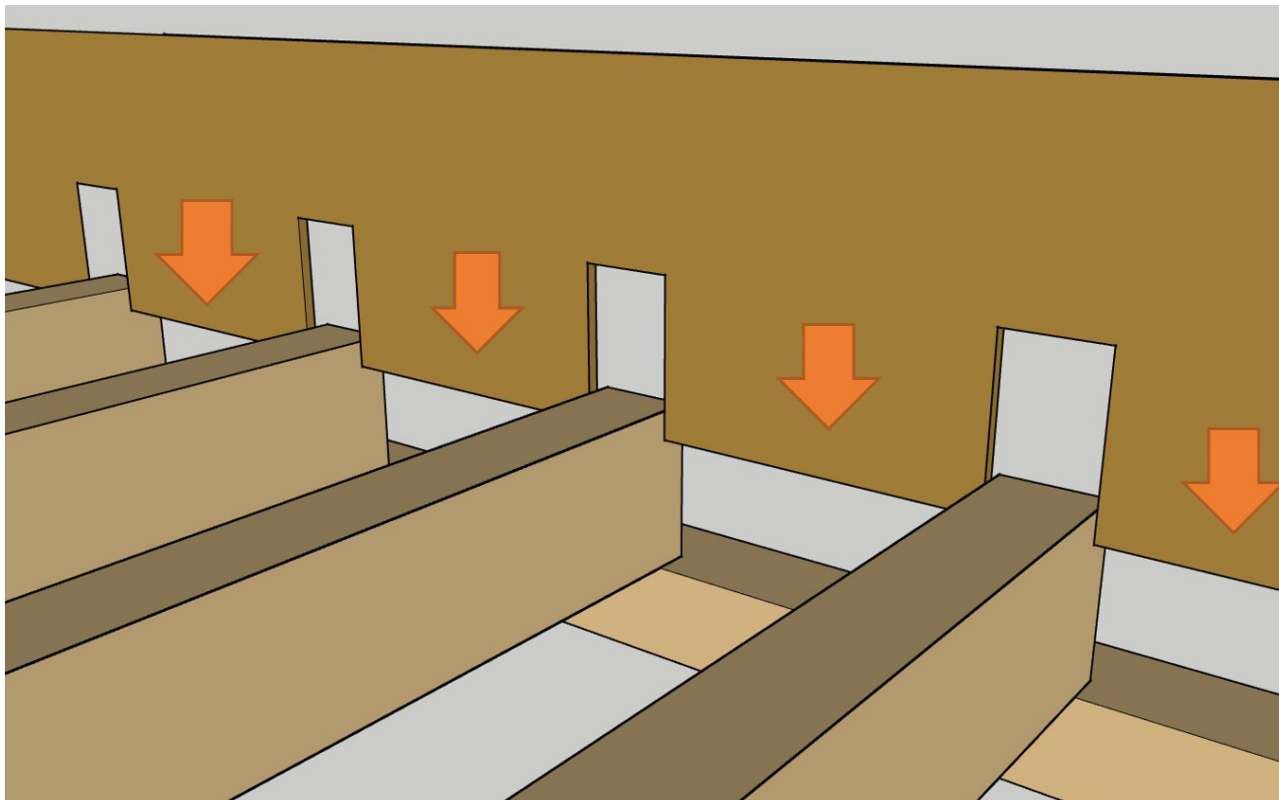


Figure 25 Saw tooth airtight board, cut to fit over floor joists. Once in place, tape airtight board to joists and air barrier on wall above and below.

For floors formed of pre-cast concrete planks the weight of the floor makes fixings unnecessary. However, the air barrier will need to be very robust if it is to pass between the floor and the wall. If using membranes in this situation, as shown in Figure 26, it is advisable to consider the use of a sacrificial timber or membrane to sandwich the air barrier and provide protection whilst the floor is installed. In this situation, sequencing is important since the air barrier around the floor needs to be installed prior to the intermediate floor. This is high risk since the air barrier at this junction will not be accessible once the floor is installed.

Generally, it is better to seal to the underside of the pre-cast concrete planks, and also to the top, in approximately the same location. Then care and additional sealing is required to ensure there is no route for air through the concrete planks, for example by filling any hollow cores and sealing the underside notch that occurs between adjacent planks. On occasion it has proved necessary to drill holes into the cores and then inject suitable low-modulus foam to seal within the planks. For permanent shuttering, the key issue is generally to ensure there is enough material to ensure the perimeter edge of the shuttering is effectively sealed.

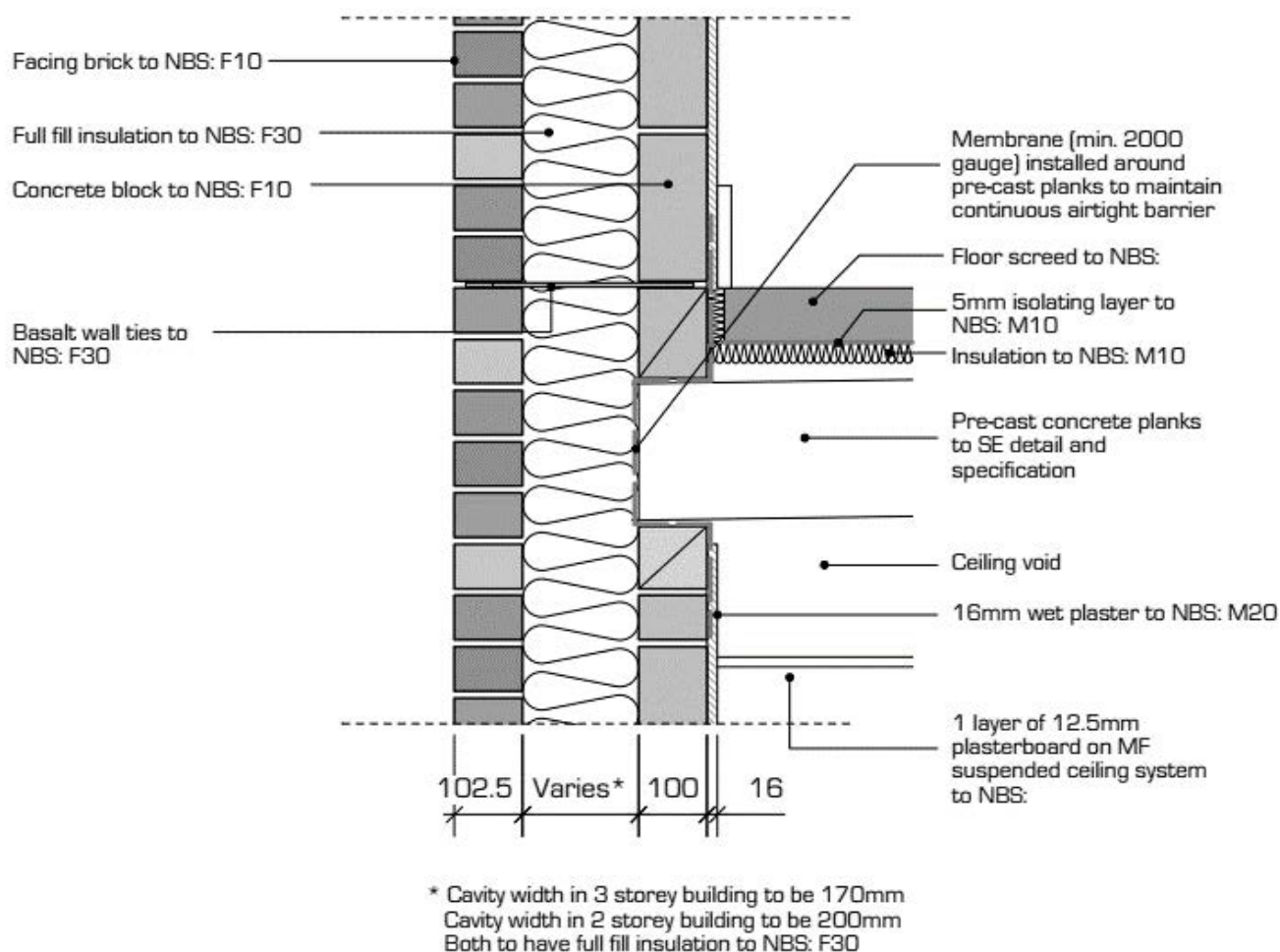


Figure 26 Intermediate floor junction with air barrier around pre-cast concrete planks. The above detail relies on a single membrane and would benefit from the use of a sacrificial membrane either side of the air barrier to provide some protection. The airtightness strategy shown above is at high risk of leakage. It is very fragile and commonly subject to damage as the pre-cast planks are craned into place.

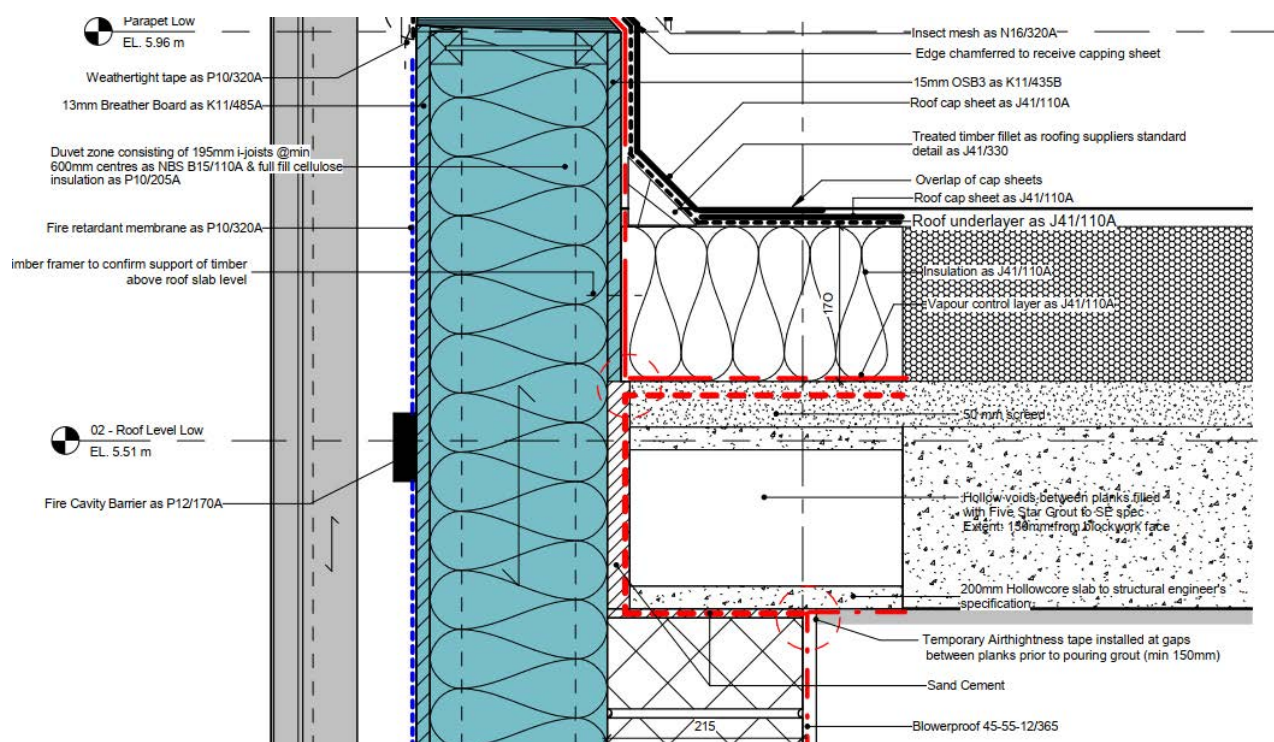


Figure 27 Alternative air barrier arrangement using grouting and sand cement around a pre-cast concrete slab.

Internal wall to external elements junctions

Some ends of internal walls will be fixed to external walls, floors and ceilings and therefore penetrate the air barrier. Hence ensuring airtightness at these locations must be considered.

Sequencing is important in such locations since the air barrier behind the internal walls must be installed first.

In the figure below a membrane is taped to the walls prior to the installation of the internal walls. A bracket is fixed through the membrane into the external wall.

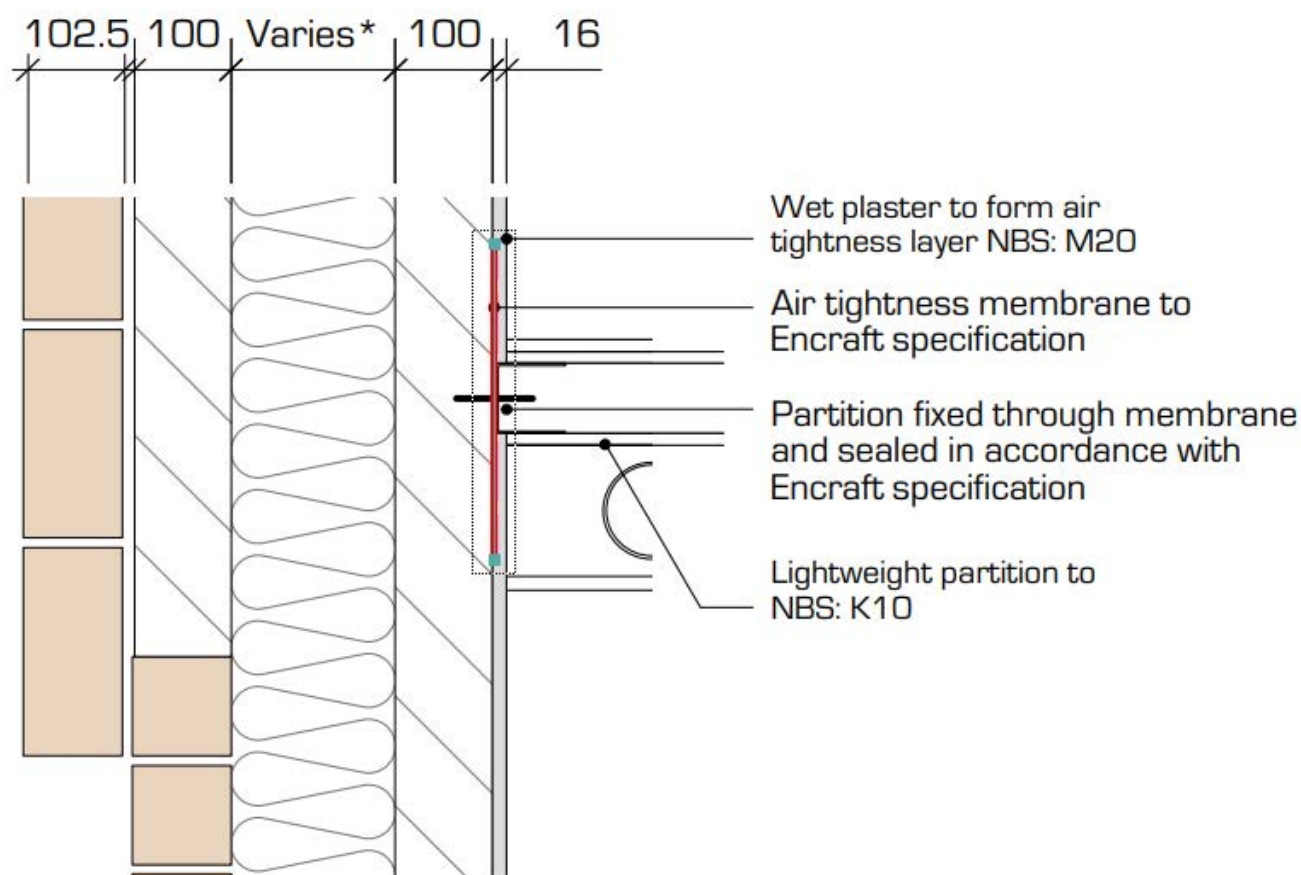


Figure 28 Internal wall to external wall junction with wet plaster air barrier.

Some internal walls may be load bearing and will require a membrane or other air barrier to be installed at a low level to join with the floor air barrier. Fixings here also need to be considered.

Where an internal party wall must continue through the ceiling build up to ensure adequate fire stopping, an effective air barrier must be installed at a high level to join with the ceiling air barrier.

Care must be taken at this junction since this part of the air barrier will not be accessible once the internal walls have been installed. This forms a hold point where some way of checking the effectiveness of the airtightness needs to be planned and executed before follow-on works can commence.

Internal wall to floor junction

Internal walls may penetrate the air barrier, whether at the screed level or in the floor, typically in masonry construction. The drawing below shows that the air barrier must be installed in the internal wall as it is being constructed. It is recommended that in this case a second barrier is installed in the internal wall to connect to the top of the screed in case of failure of the DPM in the floor.

Internal walls are usually not required to be airtight and are therefore not airtight, particularly in existing buildings. However, vertical air movement connecting to the foundations of existing building has been observed on several projects which bypasses the air barrier. Similarly, in buildings that have been extended, we find that there is generally air movement through formally external cavities that are now internal walls but link to the external facade. These issues require consideration and commonly specialist remedial works.

Lightweight internal walls (such as timber frame) often sit on top of the floor structure and therefore do not breach the air barrier.

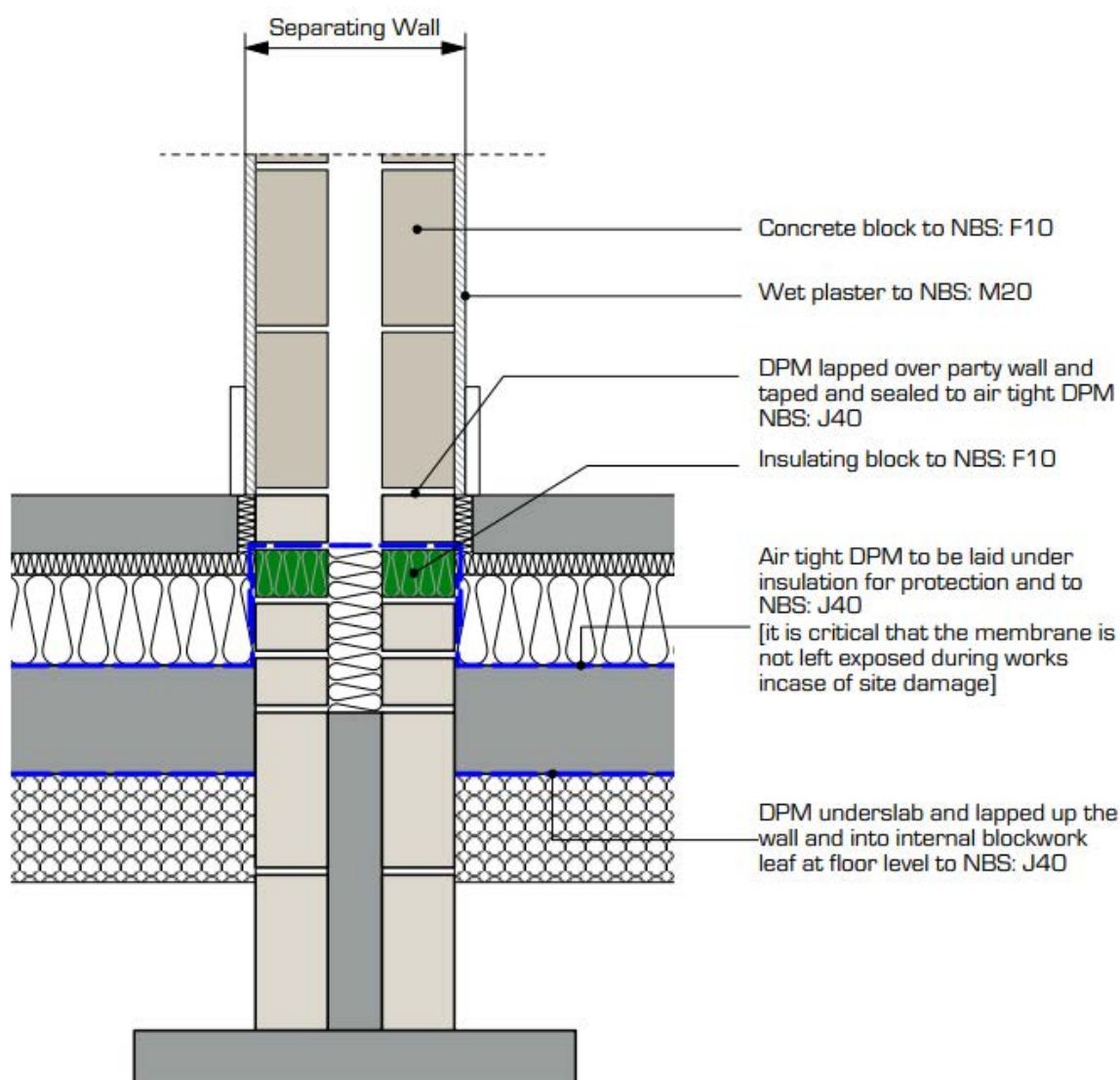


Figure 29 Internal wall to floor junction

Internal wall to roof

In internal walls built of multiple timber posts the air leakage between them is commonly disregarded but can be significant.



Figure 30 Multiple timber posts penetration roof air barrier

Party walls between separate dwellings have to be extended into the roof for fire separation. Therefore, if the air barrier is designed to be around the whole block or terrace (which may not be advisable for airtightness testing) then the air barrier must pass through the intermediate wall as shown in the drawing below.

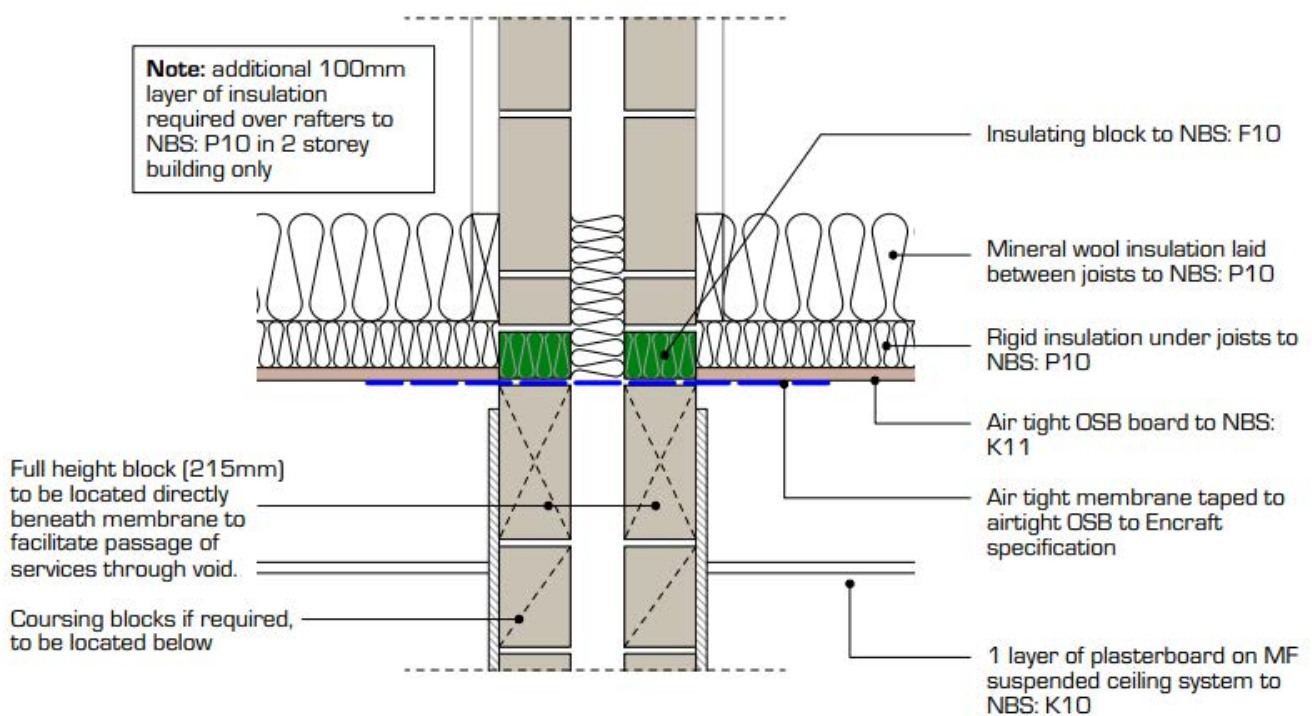


Figure 31 Party wall to roof junction

Stairs

Internal staircases may be fixed to or adjacent to a wall with an air barrier. Sequencing is important here as the air barrier must be installed prior to the structural fixings for the stairs. Care must be taken at this junction and the use of a robust air barrier or sacrificial membrane might be necessary since this part of the air barrier will not be accessible once the stairs are installed. Again, this forms a hold point where some way of checking the effectiveness of the airtightness needs to be planned and executed before follow-on works can commence.

References for more airtightness details

Low Energy Buildings Database - the information is incomplete; however, some projects feature architectural drawings and details. <https://www.lowenergybuildings.org.uk>

Passivhaus Consultants and Designers who have renewed their qualification are required to produce a full report of a certified Passivhaus and this will include junction details. <https://cms.passivehouse.com/en/training/data/designers>

Images provided by:

Elena Andreou Enhabit Ltd
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ABOUT THE AUTHORS

Dr Sarah Price

Sarah is the Head of Building Physics & Consultancy for Enhabit. She has over a decade of experience in the construction industry and specialises in sustainability, low energy buildings and retrofit. She is passionate about delivering building performance and healthy buildings for everyone.



Sarah is a Certified European Passivhaus Consultant and has been involved in many Passivhaus projects including:

- Project management of 1.2m BEIS funded project to retrofit a block of flats in Great Yarmouth and develop an innovative new whole-house cladding system, incorporating airtightness and mechanical ventilation with heat recovery. The project aims to achieve EnerPHit certification.
- Development and delivery of a series of training events and qualifications to the building construction sector on Passivhaus, EnerPHit, advanced building physics (thermal and moisture) and responsible retrofit on behalf of BECCI, CoRE and now the Retrofit Academy.
- Research on procurement in large scale Passivhaus on behalf of the University of Oxford to establish their policy of building all new Capital Projects over £1m to the Passivhaus standard.
- Passivhaus consultant for over 90 certified Passivhaus dwellings across the country.
- Pre-contract stage Passivhaus consultancy for main contractor for St Sidwell's Point, the first Passivhaus leisure centre in the UK and the third in Europe.

She has edited and now teaches the new Retrofit Coordinator Level 5 diploma that was developed in conjunction with the PAS 2035 BSI retrofit standard. Sarah sits on the BSI Retrofit Steering Task Group and is a Trustee of the Association for Environment Conscious Building.

Alex Baines

Alex is currently Head of Building Physics at Saint Gobain International. He is a specialist in sustainable construction with a particular interest in human comfort and the eradication of fuel poverty. His knowledge and passion for truly sustainable buildings is demonstrated by his status as a Passivhaus Consultant and is combined with a MSc in Renewable Energy & the Built Environment. This passion is demonstrated personally through his self-build Passivhaus project to deliver a truly airtight and ultra-low energy building envelope.



Alex is committed to developing the next set of industry standards and currently sits on the BSI Standards Retrofit Task Group, part of the government's Each Home Counts initiative, the Passivhaus Trust Technical Panel and other expert panels discussing building energy efficiency and renewable energy.

Alex has also written case studies for the UK Green Building Council, been interviewed for industry podcasts, been invited by RIBA and the AA to consult and lecture on Historic Buildings and he has regularly provided lectures and CPDs to architects, designers, local authorities and other stakeholders on a wide variety of topics.

Paul Jennings

Paul Jennings of Aldas is the most experienced airtightness tester and consultant in the UK, with over 30 years' experience. He has been an AECB member for over 15 years and a Trustee for much of that time. He is also a Director of the UK Cohousing Network.



He has presented at several AECB conferences and demonstrated the door fan test equipment at others. He has also given talks at Passivhaus conferences in Vancouver and Germany, as well as in the UK. Paul has been involved in most UK Passivhaus projects in one or more capacities.

These schemes include:

- the first UK certified domestic and non-domestic PH projects in Machynlleth, both built by John Williamson, initially tested in 2008 and then retested after a decade of operation in 2018
- the Erneley Close (Manchester), Wilmcote House (Portsmouth) and Carlton Chapel House (North London) EnerPHit block refurbishment projects
- the Agar Grove area regeneration scheme in Camden, where neglected 60s social housing will ultimately be replaced by over 500 newbuild PH units
- the Exeter Passivhaus swimming pool and leisure centre, currently under construction
- numerous individual newbuild custom- and self-build Passivhaus schemes

Paul is an experienced trainer and originated the "Airtightness Champion" concept, as well delivering numerous on-site trainings and many CPD seminars to architects and builders. He developed the 12 Steps to Airtightness approach to enable UK contractors to reliably deliver airtightness in Passivhaus and other low-energy projects.

Paul has knowledge of a multitude of airtightness products, construction techniques and materials from his extensive site visits. Paul currently works for himself under the Aldas brand, and is a Trustee of the Association for Environment Conscious Building (AECB).