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www.passivhaus.org.uk

Passivhaus primer: Contractor's guide
So you've been asked to build a Passivhaus?

Photo courtesy of BRE

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Passivhaus Primer: Contractor's guide

This contractor's guide to Passivhaus is aimed as a practical introduction and is therefore the right place to start. It addresses the issues that building contractors face when tasked with a Passivhaus project and gives simple advice and tips on how to deliver a successful outcome – a certified Passivhaus – whilst minimising cost and risk.

This guide complements the BRE Passivhaus Primer suite which provides further background to specific aspects of the Passivhaus standard.

What is Passivhaus?

Passivhaus is an advanced energy performance and thermal comfort standard for both residential and non residential buildings. The concept was inspired by a long history of vernacular buildings around the world which do not require active heating or cooling yet achieve remarkable standards of thermal comfort. Developed and refined by building physicists during the early 1990s in Germany, it is now the fastest growing energy performance standard in world and can be adapted to almost all types of climates.

A Passivhaus may be defined as 'a building in which a comfortable internal temperature is achieved solely by heating or cooling the fresh air that is introduced in order to meet the occupants' ventilation requirements.'

Since it is not possible to introduce a lot of heat to a building via the ventilation system alone Passivhaus buildings need to have a very low heating demand.

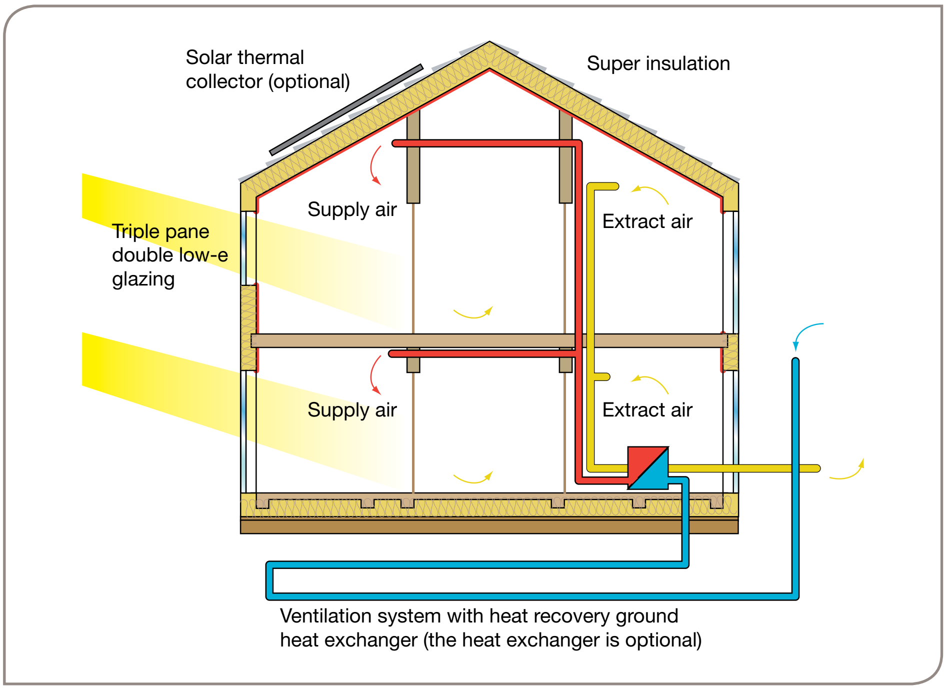
To operate with only minimal supplementary heating Passivhaus buildings require the following characteristics:

- **Unbroken super insulation**
- **Virtually thermal bridge free construction**
- **High quality triple glazed windows**

  These address the first path via which heat is lost from buildings: conduction of heat through the building fabric.
- **Very airtight building envelope**
  This addresses the second path via which heat is lost from buildings: infiltration and exfiltration of air though gaps in the building envelope, otherwise known as draughts.
- **Mechanical Ventilation with Heat Recovery**
  Which addresses the third way heat is lost from buildings: via the deliberate introduction of fresh air and extraction of stale air for the purpose of ventilation.

Most of the issues faced by contractors commissioned to deliver Passivhaus buildings come down to being able to accurately cost and reliably implement these five key characteristics of Passivhaus design, shown in Figure 1.

Figure 1 Passivhaus schematic



Certification requirements

In order to have a building certified as a Passivhaus the following performance criteria must be met:

Building energy performance	
Specific heating demand or Specific peak load	≤ 15kWh/m^2.yr ≤ 10 W/m^2
Specific cooling demand	≤ 15kWh/m^2.yr
Primary energy demand	≤ 120kWh/m^2.yr
Elemental performance requirements	
Airtightness	≤ 0.6 ACH (n50)
Window U value	≤ 0.80 W/m^{2}K
Services performance	
MVHR heat recovery efficiency	≥ 75% *
MVHR electrical efficiency	≤ 0.45 Wh/m^3
*Note: MVHR efficiency must be calculated according to PHI standards not manufacturer's rating	

Passivhaus certification is awarded on the basis of 'as built' rather than 'as designed' performance, therefore pressure test results, commissioning certificates and a record of the build must be submitted before a certificate can be issued by the BRE, or other certifying body.

Construction methods and materials

The Passivhaus standard defines the building performance and thermal comfort of occupants. It is not prescriptive with regard to the construction method. The architect of a Passivhaus may therefore produce designs based on typical UK constructions, such as timber frame or masonry cavity wall. Alternative constructions more typically found in continental Passivhaus designs such as solid masonry with external insulation may also be specified along with modern methods of construction (MMC) such as structural insulated panels (SIPs) or insulated concrete formwork (ICF) as illustrated in Figure 2.

As a dedicated energy performance standard, Passivhaus does not directly address the wider sustainability issues facing the construction industry. It does not, for example, involve detailed assessment of the environmental impacts of specified materials, or site waste management concerns.

Passivhaus complements, and can be used alongside, more holistic sustainability assessment standards such as the Code for Sustainable Homes (CSH) and BREEAM (Building Research Establishment Environmental Assessment Method) to deliver buildings which are both extremely energy efficient, comfortable and address a broad range of sustainability issues.

Passivhaus building have been delivered using 'standard' building materials such as concrete blocks, expanded polystyrene (EPS) and polyisocyanurate (PIR) insulants. Other developments have used lower environmental impact materials such as responsibly sourced timber, cellulose or wood fibre insulation and extruded clay 'Zeigel' blocks. Whilst the later approach will typically result in a lower carbon and environmental footprint both approaches are valid for the construction and certification of Passivhaus buildings.

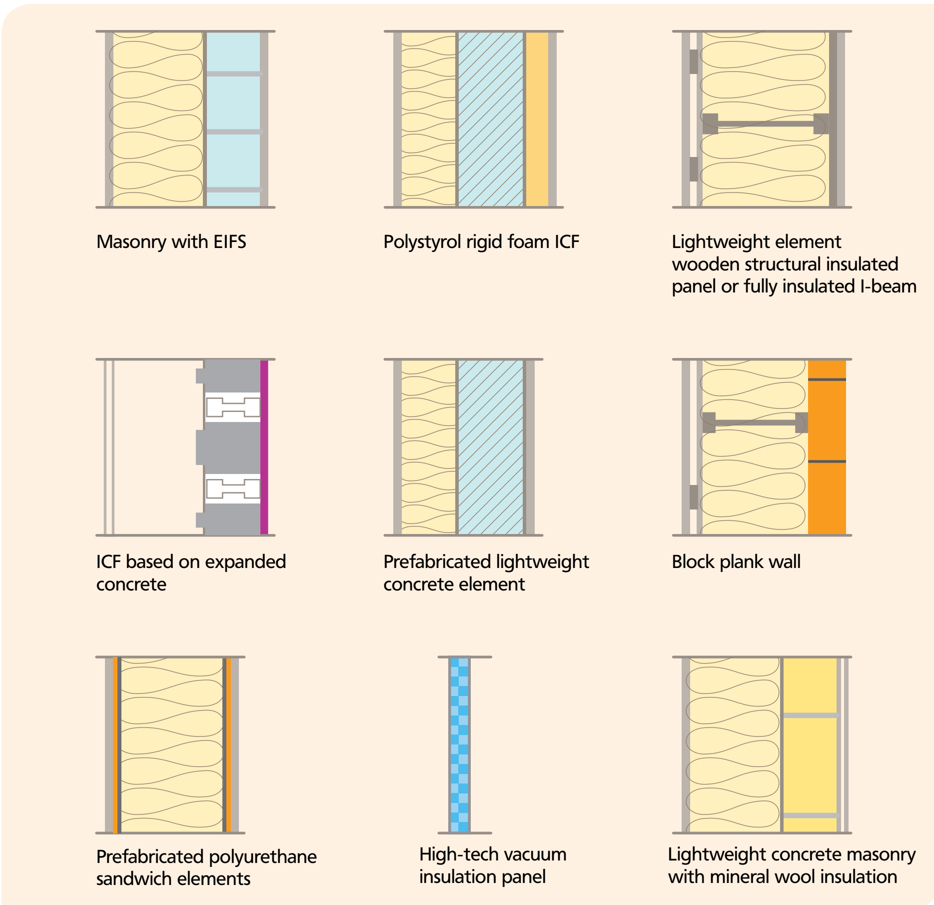


Figure 2 Passivhaus construction possibilities

Renewable energy technology

Passivhaus aims to achieve a very high level of inherent energy efficiency. The certification requirements are based on annual energy consumption in kWh per m^2 treated floor area. This differs from the UK Building Regulations which uses annual carbon dioxide emission per m^2 floor area as the compliance metric. Therefore, unlike the UK Building Regulations, Passivhaus does not allow energy use and the resultant emissions from a building to be 'offset' using on site generation of zero carbon electricity. Any such generation is specifically excluded from Passivhaus certification.

The use of solar thermal systems to meet part of the domestic hot water heating demand is however allowed and expected. Any PV panels added to a Passivhaus cannot be used to offset reduced standards of energy efficiency. Therefore a PV or renewable energy equipped Passivhaus is the most robust starting point in the drive to zero carbon buildings.

Figure 3 shows the Larch house in Ebbw Vale, a certified Passivhaus that also meets the requirement of Level 6 of the Code for Sustainable Homes.

Figure 3 The Larch house, Ebbw Vale

Delivering Passivhaus

Ensuring completion of the design

Delivering a Passivhaus requires an integrated design approach; therefore it is unlikely to be possible to commence the construction phase of a project before the vast majority of the design work is complete. Starting before detailed design work and Passivhaus planning has been completed may result in compromises to the building performance that threatens its certification. For example it is hard to rectify the level of insulation in the ground floor or the design of the floor to wall junction detail, after this has been constructed. Therefore before commencing site work it is important to check that the design work is complete and that all the required drawings are in place; including plans, sections and clearly annotated details for all junctions between building elements (e.g. floor to wall), components (e.g. window to wall) as well as building services layouts. Figure 4 shows a good example of a wall to floor junction developed by Bere Architects for the Ebbw Vale project, showing the level of detail Passivhaus design requires.'

Construction materials

High quality buildings require high quality materials that are delivered and installed in good condition. Therefore the handling of materials and their protection on site matters to the performance of the completed Passivhaus. Substituting materials during construction is not advisable as the use of inferior or non-certified products could jeopardize Passivhaus certification.

Insulation for example must conform precisely to the specification and can only be accepted if the packaging is undamaged, correctly labelled and stamped with a 'CE' kitemark. During installation it must be laid in a continuous manner, leaving no gaps between panels or rolls. Even a 5mm gap between insulation panels will result in 'thermal bypass' as warm air moves through the gap significantly increasing the effective U value of a completed wall. Insulation panels must therefore have square edges to ensure that there are no gaps – and this means protecting the insulation during transportation, storage and handling on site.

The extremely low energy consumption of Passivhaus buildings means that drying out of materials can consume a considerable proportion of the heating energy used during the first year of occupation. Materials should therefore be kept dry on site.

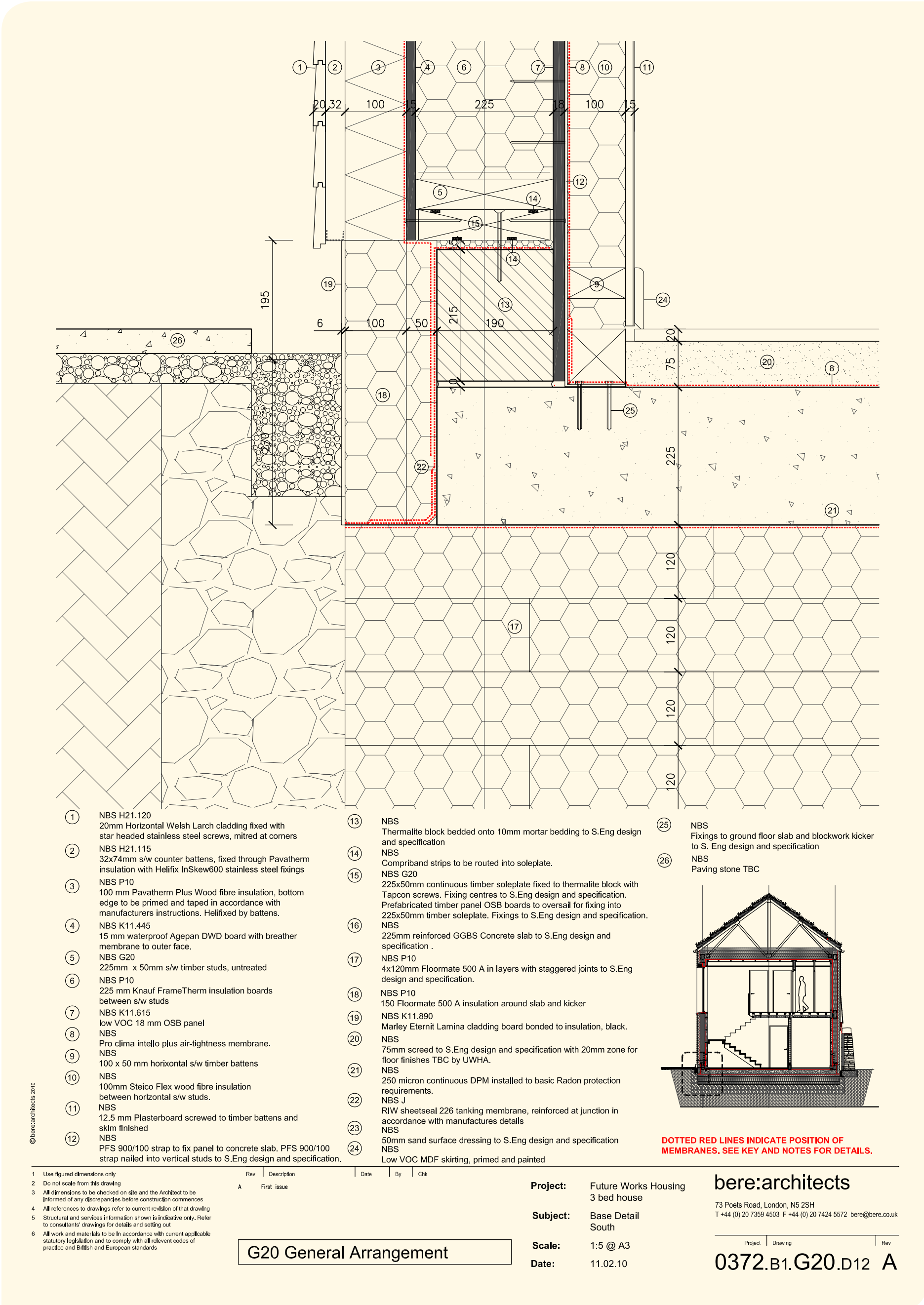


Figure 4 Wall to floor junction developed by Bere Architects for the Ebbw Vale project

Building services components

Indoor air quality, which should be exceptionally good in Passivhaus buildings, will be spoilt if ductwork, MVHR and control systems are not adequately protected during their storage and installation. It is essential that all ductwork, MVHR units, attenuators, filters and control systems are stored in a dry, dust free environment. For this reason it is advisable to ensure that open ends of ductwork and MVHR spigots are kept completely sealed until they are fully installed. Any dust or dirt entering the ductwork or MVHR systems will need to be removed before commissioning and it is far easier and less costly to avoid this situation altogether.

Building services, Racecourse, Gentoo Homes

Insulated DHW pipes

Sequencing

As with any construction programme, implementing the Passivhaus standard on-site requires that jobs are sequenced correctly. Passivhaus however has some specific requirements in order to achieve the required level of air tightness and thermal bridge free junctions. Ensuring an airtightness of 0.6 ac/h @n_{50} requires a continuous air barrier. An airtight construction of this standard cannot be achieved through last minute attention to detail and expanding foam alone!

Sequencing is about forward planning – so that complex and interdependent tasks are scheduled in the most efficient manner and materials are delivered to site when needed. The sequencing of a Passivhaus build requires a detailed understanding of the assembly process as well as critical stages in the build. A series of briefing meetings between the designers and contractors will be needed to ensure that the correct sequencing of key stages is clearly understood at the outset. The clerk of works and site manager should be present during these briefings. Project management Gantt charts should highlight critical stages in the project sequencing, including any special ordering or preparatory requirements.

Tool box talks and site briefings should be scheduled prior to critical stages in the build programme. Detailed production drawings annotating any special sequencing and fixing procedures should be displayed on-site so that site operatives are able to verify detailed installation procedures.

Five steps to achieving Passivhaus on-site

1 Super insulation

The first aspect of implementing a Passivhaus design that differs from standard UK construction is the amount of insulation that must be incorporated into the building envelope. Up to 300mm, and sometimes more, is common in Passivhaus buildings. This will require familiarisation with potentially new forms of construction such as externally insulated solid masonry walls, or with new details such as the installation of windows into 300mm cavities.

Construction of junctions will also differ from the current generation of buildings in order to accommodate this thickness of insulation. For example, trussed rafters are likely to have up stands to ensure the full thickness of insulation can be carried right into the eaves. These details and the method of fixing the insulation must be determined before the commencement of work on site. These procedures will be unfamiliar to the majority of the UK industry and additional training and site management is likely to be required to ensure their proper implementation on site. Sufficient time for familiarisation, training and site briefings should be incorporated into the build schedule.

2 Thermal bridge free construction

Minimising thermal bridging is an issue for both designers and constructors and can result in very simple details for certain methods of construction: for example an insulated raft foundation combined with an externally insulated solid masonry wall provides a very simple floor-wall junction. Other details will be inherently more complex, for example the installations of weather tight and thermally bridge free roof lights (which may be best avoided in Passivhaus building for this very reason).

Implementation of thermal bridge free details requires forward planning and the availability of the correct materials at the right time during the construction process. If for example a single course of aircrete block work is required at the base of a wall constructed from aggregate blocks, the materials must be on hand to be incorporated at the appropriate time.

The design must be implemented according to the designers drawings, so the addition of timber studs or noggins where none are shown on drawings is not acceptable when constructing Passivhaus buildings as it will result in additional thermal bridging.

3 Triple glazing

This is possibly the single most expensive additional investment needed to achieve the Passivhaus standard. Fine tuning the window specification is an important part of achieving the Passivhaus standard and the window specification may not be finalised until late in the design process. Because lead times for manufacture and delivery of glazing and doors can be long it is advisable to place orders as early as possible to avoid delays on site.

Ensuring that the correct glazing specification has been delivered to site is the first step in ensuring proper installation in accordance with the design. This involves comprehensively checking the order. Not only should the window dimensions and reference codes be checked off but so should the product specification to ensure a mistake has not been made at the factory.

Each window and door should be uniquely coded with the following information:

- Frame type and U_F value (EN 10077)
- Glazing type and U_G value (EN 673)
- Solar energy transmission g-value (EN 410)
- Daylight transmission (EN 9050)
- Glazing and gap dimensions
- Spacer type used
- Special low emissivity coatings
- Inert gas fill type

It is likely that the designer has specified a unique g-value for the glazing of each façade, and possibly for each opening as this is a way of fine tuning the useful solar gains that enter the building. It is therefore possible that two windows which appear to be identical with respect to frame type and dimensions are actually intended for different openings. It is essential that the windows are correctly coded for each opening in line with the designer's window specification.

Correctly installing Passivhaus glazing and doors is a specialist job and technical support and training from the manufacturer is needed. Triple glazed systems are particularly heavy and special lifting equipment may be needed to lift larger windows and doors in to place. Prior to installation the window openings should be inspected and cleaned of any dust or debris. Priming of the reveal surfaces may also be required if proprietary air tight tapes are being fixed to masonry.

To achieve a thermal bridge free window connection windows may be designed to 'float' in the opening which is subsequently back filled with foam insulation once the window is in place. Air cushions and other positioning devices will allow the installer to works closely to the designer's drawings at this stage where millimetre tolerances may make the difference between a bridged and a bridge free connection, which can be seen beneath the window frame shown being installed in Figure 5

The final critical aspect of glazing installation is the air tightness of the units once installed, and this can only be checked on site during the air pressure test. It is therefore important that an experienced installer is on site during the pressure test to make any additional adjustments to the window and door gearing necessary. Sufficient time should be allocated in the pressure testing and air leakage detection schedule for this procedure.

Figure 5 Window frame installation

Photo courtesy bere:architects

4 Airtight building envelope

Airtightness is central to the Passivhaus concept and the standards required go far beyond Part L (2010) requirements. A detailed air tightness strategy should be specified by the designers and indicated on all production drawings. The airtight layer is normally located on the warm side of the insulation layer and should not be confused with a wind barrier (vapour diffuse) membrane on the outside of a timber frame building.

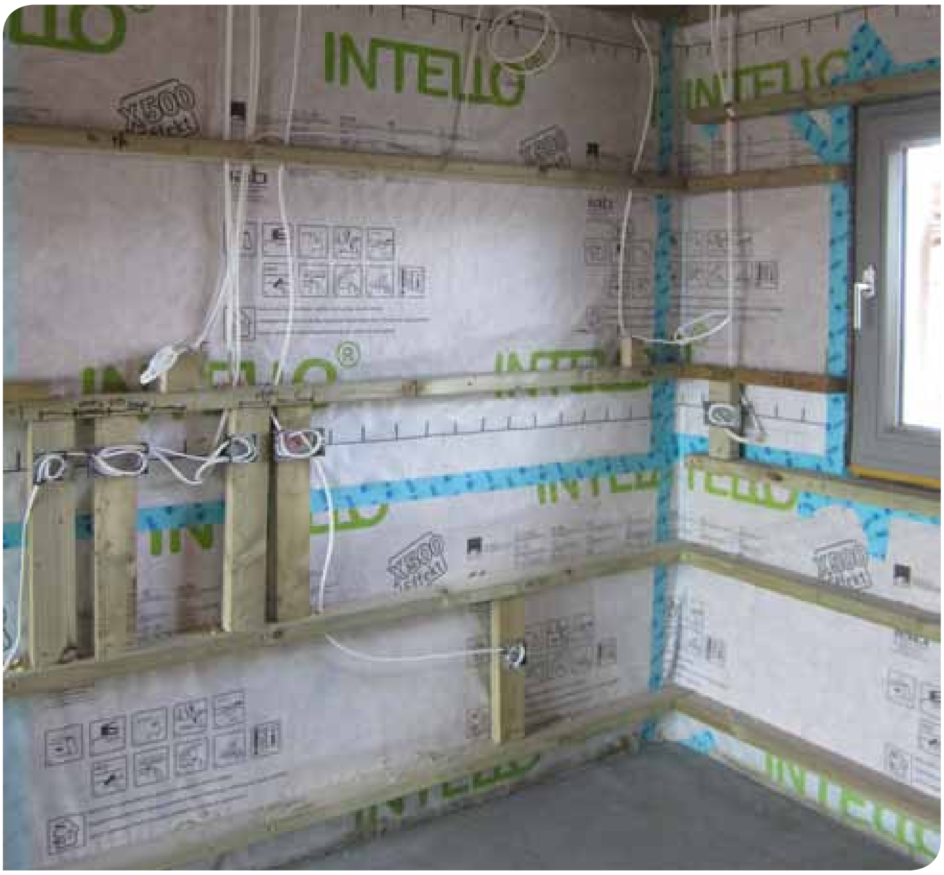
In order to ensure that compliance with the designers intentions are maintained throughout the build an 'airtightness champion' should be appointed. Ideally this person would be a site operative who will be present throughout the build; someone who thoroughly understands and can communicate the designer's air tight strategy.

In some cases the airtight barrier will have to be installed or partially installed during early stages of the build when it would not normally be necessary to address these issues. For example, to ensure continuity of an internal air tight barrier across the intermediate floor to wall junction in a timber frame, a section of the air barrier will need to be laid over the top of the ground floor wall construction before the first floor joists (or cassettes) are added. The air barrier will then need to be returned around the outer ends of the joists or floor cassettes so it can continue up the inner side of the first floor wall. Failure to install the air barrier at this stage would jeopardise the final air tightness as the alternative solutions are far less robust.

In masonry construction air tightness is likely to be achieved using wet plaster, it is necessary to carefully parge walls before intermediate floors and partition walls are installed, and before any service runs hinder access to walls and prevent the installation of a continuous barrier. Junctions between masonry and joinery require special attention as proprietary air tight tapes will be needed to ensure a continuous air tight seal at these locations. Plastering lathes and mesh should be used to mechanically fix and seal any tapes back to the parge coat.

Ideally the air tight layer should be located behind the services void, as shown in Figure 6, and on no accounts should plasterboard be used as the air tight layer. Any departures from or changes to the air tightness strategy shown on the drawings needs to be communicated to the Passivhaus consultant or designer before they are made.

Figure 6



A minimum of two pressure tests will be needed, and three are advisable in some cases. The first should be conducted at the end of first fix when the glazing and doors have been installed, but the airtight barrier is still open to inspection. It is recommended that the key contractor, clerk of works and site operatives are present during the pressure test in order to identify and remedy any defects in the air tightness layer.

A second pressure may be carried out once the services have been installed. This is good practice particularly in timber frame construction where service run fixings and cabling may have damaged the air tight membrane.

A final test must be carried out at the completion of works. This test is needed to verify the airtightness after all of the building services have been installed and commissioned. In England this test must be carried out by a competent person registered with the British Institute of Non Destructive Testing (BINDT) and carried out in accordance with BS EN 13829 test conditions.

Once the n_{50} test has been passed the test certificate should be forwarded to the Passivhaus certifying body (BRE Passivhaus UK) as evidence of compliance with the air pressure testing requirement. Further information on preparing for the air pressure can be found in the Passivhaus Primer – Air pressure testing.

5 Ventilation system

Passivhaus buildings are dependent on their MVHR system to ensure good indoor air quality. The correct design, installation and functioning of the MVHR system mean it will save around five times more energy than it consumes. Inappropriate installation or the specification of low quality components will cause noise intrusion to occupied areas of the building, irritating occupants.

The following checks should be made:

– The system is complete and installed correctly, with sound attenuators between the MVHR unit and distribution ductwork and between rooms. For certification purposes maintain a photographic record during the installation, particularly at penetrations of the intake and exhaust ducts through the building envelope. Check that vapour tight insulation and top-hat seals have been used on the intake and exhaust ducts.

– All installed ductwork and the MVHR unit must be clean inside and free from site dust. Filters should be clean and dry and in place to protect the unit at start up. These checks should be made before stating the system for the first time, or dust may be distributed throughout the entire ductwork.

– All components that require maintenance such as post heater, filters, duct cleaning access points, fire dampers if fitted, and balancing valves are accessible.

– UK fire regulations have been adhered to, for example air movement between rooms is via door under cuts, and that there are not vents at the top of fire doors.

– The system has been properly commissioned by the Building Services engineer and commissioning certificates have been completed for Passivhaus certification. O&M manuals or a comprehensive user guide should be available to occupants at handover.

MVHR unit, Racecourse, Gentoo Homes

Summary and conclusion

Delivering a Passivhaus building on budget and on time for the first time can seem like a daunting prospect. But as the scientist Louis Pasteur once said 'chance favours the prepared mind'. By taking the time to read this primer you are hopefully better informed about the key issues that set a Passivhaus apart from a conventional build

Passivhaus is not a passing whim but rather a logical step change as we progress to a zero carbon low energy future. By working collaboratively with the design team, defining clear roles of responsibility and using an experienced supply chain, up-skilling to meet the Passivhaus standard can be a rewarding and fruitful process.

If this Primer has whet your appetite to learn more about Passivhaus check out the other Passivhaus primers and training courses on offer from the BRE Passivhaus UK website www.passivhaus.co.uk

Photo courtesy bere:architects

Passivhaus glossary

Specific heating demand

This is the annual space heating requirement of the building, over the course of the year, normalised to the treated floor area of the building in m^2. It is a measure of energy and is therefore measured in kWh. The limiting value for a building to comply with the Passivhaus standard is ≤ 15 kWh/m^2.yr

Specific cooling demand

This is the annual space cooling requirement of the building, over the course of the year, normalised to the treated floor area of the building in m^2. It is a measure of energy and is therefore measured in kWh. The limiting value for a building to comply with the Passivhaus standard is ≤ 15 kWh/m^2.yr

Specific heat load

This is the heat output in Watts (i.e. it is a measure of power) required of the heating system on the coldest day of the year, normalised to the treated floor area of the building in m^2. The limiting value for a building to comply with the Passivhaus standard is ≤ 10 W/ m^2.

Primary energy

Primary energy is the energy that must be extracted from the environment in order to deliver energy at the point of use. For example around 3 units of energy must be extracted from the earth in the form of fuel (gas or coal) in order to deliver a single unit of electricity to a building. The limiting value for a building to comply with the Passivhaus standard is ≤ 120 kWh/m^2.yr

n50

n50 refers to the German standard for measuring airtightness of building in air changes per hour when the building is pressurised and then depressurised. This differs from the UK method known as q50, which specifies the air tightness of building specific to the envelop area in m^3 of air leakage through each m^2 of building envelope when the building is depressurised. The limiting airtightness value for a building to comply with the Passivhaus standard is ≤ 0.6 ac/h @ 50 Pascals.

Our services

Consultancy

All members of BRE's Passivhaus team have completed the Certified Passivhaus Designer training and are able to provide expert advice at all stages of the development, including:

- Design Concept and Strategy
- Low energy design advice
- Construction techniques
- Toolbox talks for on-site inductions and management
- Generating Passivhaus information packs for specific buildings
- Thermal modelling of construction details

Certification

BRE is registered with the Passivhaus Institut as an official Certifier for Passivhaus buildings

- Pre assessments
- Full Building Certification
- Reduced rate certification via BREs Passivhaus Certification Scheme (PCS) for qualified CEPH Designers

Testing

- Airtightness detailing and testing to n50 and q50 testing methods
- Airtightness compliance reports for Passivhaus Certification and UK compliance
- IR Thermography
- Co-heating testing
- Monitoring and testing for 'as built' performance
- Post occupancy surveys

Training

BRE is registered with the Passivhaus Institut as an official training centre for Passivhaus training courses

Certified Passivhaus (CEPH) Designer

A fast track training programme leading to the examination required to become a fully Certified European Passivhaus (CEPH) Designer. This qualification is recognised as the industry standard for those intending to work professionally as a Passivhaus designer in the UK and abroad. BREs CEPH Designer training course has one of the highest pass rates in Europe which has been acknowledged by Dr. Wolfgang Feist.

One-day Passivhaus Introduction and Workshop

An introductory course and workshop is aimed at all those with an interest in low-energy design, construction and the Passivhaus standard. It introduces the delegates to the Passivhaus principles, walking them through best practice construction techniques whilst highlighting the outline specification and certification criteria. The course also introduces the delegates to the Passivhaus Planning Package (PHPP).

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Passive House Certifier
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Quality-Approved Energy Retrofit with Passive House Components
Passive House Institute

DESIGNER
CERTIFIED PASSIVE HOUSE DESIGNER


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BRE Trust
The BRE Trust uses profits made by BRE Group to fund new research and education programmes, that will help it meet its goal of 'building a better world'.

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Other Primers in this series:
Passivhaus Primer: Introduction
Passivhaus Primer: Designer's Guide
Passivhaus Primer: Airtightness Guide

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