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Methods and techniques for airtight buildings

F.R. Carrié, R. Jobert, V. Leprince

Contributed Report 14

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- Lindab
- Soudal
- Tremco illbruck
- Wienerberger

TightVent Europe
BUILDING AND DUCTWORK AIRTIGHTNESS PLATFORM

The TightVent Europe "Building and Ductwork Airtightness Platform" was launched on January 1, 2011. It has been initiated by INIVE EEIG (International Network for Information on Ventilation and Energy Performance) with the financial and technical support of the following founding partners:

Building Performance Institute Europe, European Climate Foundation, Eurima, Lindab, Soudal, Tremco illbruck, and Wienerberger.

Since November 2011, BlowerDoor GmbH and Retrotec have joined TightVent and thereby bring air leakage measurement expertise to the consortium.

The platform aims at facilitating exchanges and progress on building and ductwork airtightness issues, namely through the production and dissemination of documents and the organization of events.

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Abstract

This paper gives an overview to the design principles and construction methods for building airtightness. Its primary objective is to disseminate basic information on steps to follow at design stage as well as on tightening products and frequent field issues.

It stems from the MININFIL project run between 2009 and 2010 under the PREBAT programme with the support of ADEME. In particular, it can be read as an introduction to the over 150 construction details developed within this project.

Introduction

There exists a significant body of literature on energy and indoor air quality impacts of envelope leakage. In fact, this topic has been studied since the 70s and has lead to many publications, in particular within the Air Infiltration Centre established in 1979 that has become the Air Infiltration and Ventilation Center (AIVC) since 1987. Most available literature on envelope leakage characterization, measurement methods, airflow modelling can be found in the publication database developed and managed by the AIVC at www.aivc.org.

While it was a very active field of investigations in the 70s and 80s, interest for this issue has decreased in the 90s and until the mid-2000s. An important exception lies in low-energy building approaches that have encouraged pursuing efforts on research and development of methods and products. The CEPHEUS[1] project (www.cepheus.de, 1998-2001) is a good illustration of work undertaken in the late 90s on very low-energy buildings that addressed specifically envelope airtightness issues. The Passivhaus standard developed since 1988 with the joint work of Professors Bo Adamson (University of Lund, Sweden) and Wolfgang Feist (Institute for Housing and the Environment, Germany) is another corner stone for envelope airtightness developments. Because extremely low leakage levels are required in these types of buildings (n_{50} below 0.6 ach), some professionals have progressively developed methods and products to reliably tighten building envelopes. Therefore, while these techniques were quite crude in the first passive houses built in the early 90s, the development of new seals, bonds, and barriers has allowed designers to be more confident to meet those stringent requirements. However, this market remained quasi-confidential until 2005.

Since 2005, there is a revived interest for topic with the recent steps taken by many countries to generalize very low-energy buildings. This trend has been clearly identified in the ASIEPI[2] project (www.asiepi.eu, 2007-2010) together with the need for dissemination on methods and products to achieve good airtightness. Growing experience on this issue shows that generalizing airtight envelopes is a great challenge that calls into question the training of architects, engineers and craftsmen. This is one fundamental reason behind the TightVent Europe initiative (www.tightvent.eu).

The objective of this paper is to disseminate practical information on methods and techniques. It starts with key quality principles, continues with a description of the steps to follow at design stage, proposes classification of tightening products, and explains frequent field issues.

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[1] Cost Efficient Passive Houses as European Standards, a project within the THERMIE Programme of the European Commission, Directorate-General Transport and Energy. Project Number: BU/0127/97, duration: 1/98-12/01

[2] Assessment and Improvement of the EPBD Impact, a project within the IEE SAVE Programme of the European Commission. Project n°EIE/07/169/SI2.466278, duration: 10/07-03/10

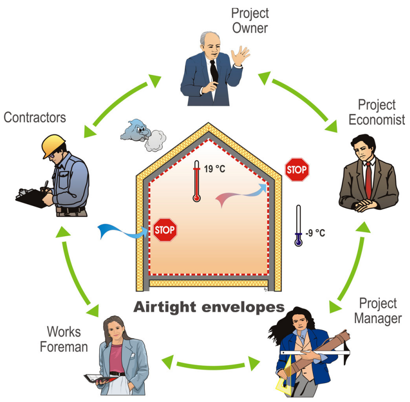
1. Key quality principles for achieving airtight envelopes

Achieving envelope airtightness involves a chain of actors in the building construction process ranging from the building designer to the building workers. To be successful, each actor must be aware of the underlying principles of an airtight envelope.

The purpose of this chapter is not to give a discourse about fundamentals of a quality management approach, but rather to point out key principles that are critical for envelope airtightness. As we will see later, good airtightness not only relies on the quality of the products and their installation but also on the overall scheme designed to achieve airtightness, including the treatment of all interfaces at potential leakage sites. 90% of the envelope can be remarkably well designed and realized for excellent airtightness, but if the remaining 10% is poorly treated, the result can be very far from expectations. Similarly, it only takes one craftsman to neglect sealing one penetration to compromise the result.

Envelope airtightness must be viewed as a system which is specified in the programme, designed, detailed in calls for tender, checked and corrected if necessary (Figure 1). Because it remains uncommon today for most professionals, it is important to take time to explain each step. There exists ready-to-use dissemination information in some countries that experience great success. Examples and base material can be found on the ASIEPI and CETE websites (www.asiepi.eu, www.cete-lyon.developpement-durable.gouv.fr), but experience shows that local or at least country-specific information is better integrated by building professionals.

At the beginning of the execution phase, it is useful to have a formal meeting to recall the performance desired and key issues specific to this building to the contractors. This meeting is the opportunity to stress the importance of airtightness for the project owner and the architect, and to explain the control framework during the construction process and at commissioning.



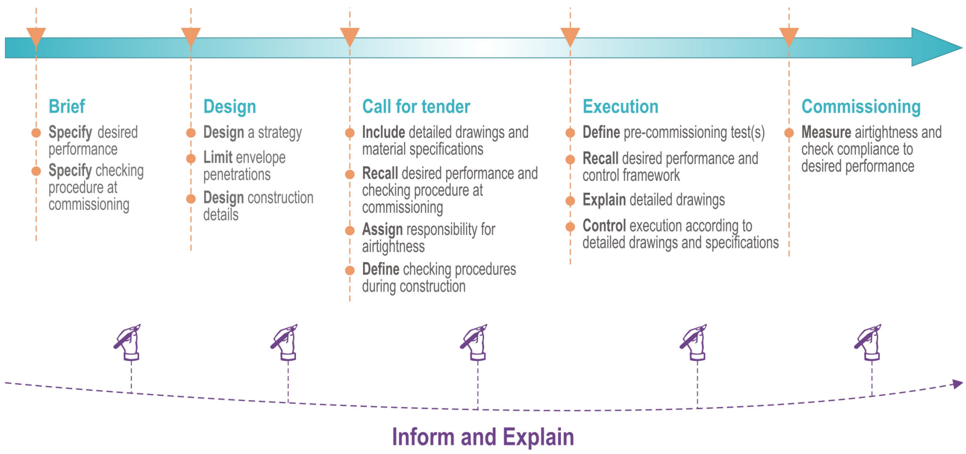


Figure 1. Flow chart of key steps to achieve airtight envelopes.

2. Airtightness design

2.1. Overall design principle

The designer must identify the junctions that must be sealed and specify adequate tightening products and methods. The airtight and continuous "skin" method is straightforward in principle. The designer should draw the junctions at a scale of 1:5 to 1:10 approximately for a detailed description of the tightnening methods.

The fundamental principle for designing good airtightness is to think of it as a continuous and tight skin around the acclimatized volume (Figure 2). In horizontal and vertical section, the designer must be able to follow this virtual skin with a pencil, without lifting it. Each junction between building components must be analysed to define the materials that will durably ensure airtightness at this location. When treating one given junction, the designer must keep in mind the continuity of the skin to the adjoining joints (Figure 3).

Note that the "skin" can take several forms: it can be plaster on a vertical wall, and then a vapour barrier for the roof, these two parts being bound with an appropriate membrane for instance.

From an airtightness point of view, the "skin" can either be inside or outside or both, however, it seems more commonly designed from the inside in passive houses. Note that the use an external barrier to achieve airtightness is a subject of research that is very promising regarding the envelope leakage, but that needs to be further studied with regard to condensation damage, a potential side effect being that the inside vapour barrier be neglected (Langmans et al, 2009). It has already been shown that this solution was risky in cold climates regarding condensation (Geving et al., 2010). One conclusion of that study was that the outer barrier should have no more than a tenth of the vapour resistance of the inner barrier.

Experience shows that construction details are often insufficiently precise on the way sensible joints must be sealed, which is detrimental for two reasons: first, it gives an inappropriate signal to the contractors and craftsmen who do not feel the will of the architect to correctly treat those junctions; second, the craftsmen who are left alone have to improvise their own solutions that can be inadequate. We recommend each junction to be drawn at a scale of 1:5 to 1:10 approximately to clearly see how airtightness will be achieved.

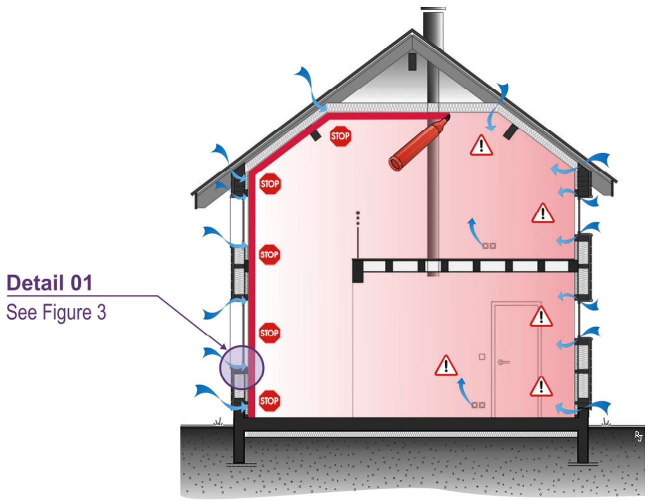


Figure 2. Illustration of the principle of the airtight and continuous "skin".

Detail 01 (from figure 2)

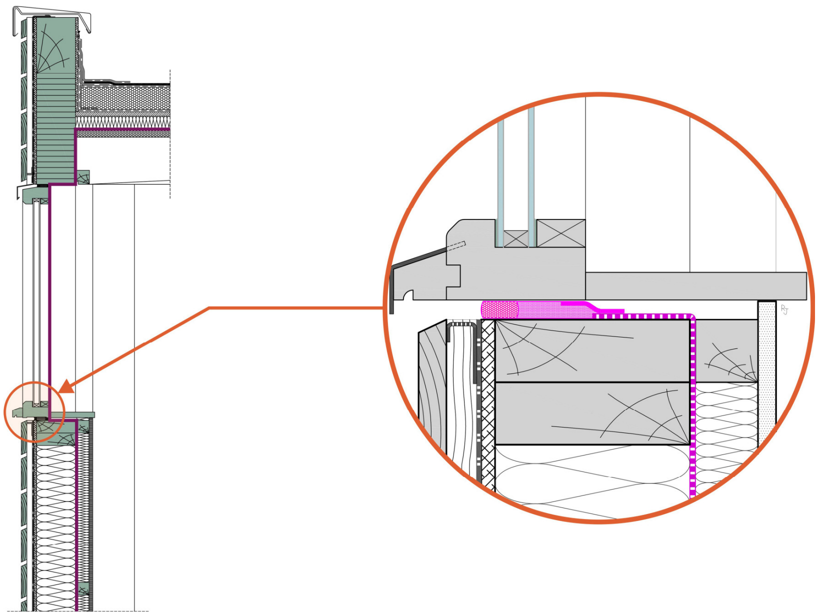


Figure 3. Illustration of the continuity between several junctions.

2.2. Envelope penetrations

> Envelope penetrations may be unavoidable, however, they should be minimized and treated consistently with the airtight "skin".

Because each envelope penetration (e.g., for electricity supply) is a potential leakage site, the general advice is to limit their number. For instance, the Passivhaus institute recommends a maximum of 15 penetrations.

The electrical network is often a source of irremediable problems. One effective solution is to have only one penetration for the main electricity supply to the electrical cabinet, and then to have the entire network distributed within the envelope (Figure 4). The problem is therefore reduced to sealing the penetration for the mains supply cable, which is quite simple. If this solution cannot be applied, the alternative is to seal each perforation which is extremely tedious. Several products are available on the market for this specific application. Note however that if the electrical conduit allows air to pass, the designer must see that this does not allow air to leak to outside.

The same rule (i.e., one main penetration and a network distribution within the conditioned space) applies to water and gas supply lines.

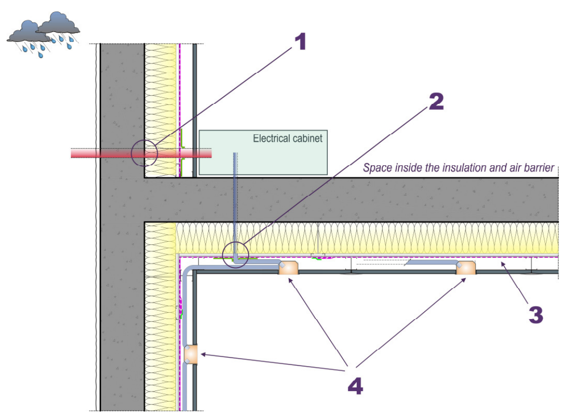


Figure 4. Penetration for electricity supply.

It is useful for building professionals to be aware of common leakage sites. These are listed and classified in Figure 6 and Figure 5.

2.3. Common leakage sites

Common leakage sites are identified in Figure 6 and in Figure 5. In Figure 6, the sites are classified in 4 categories.

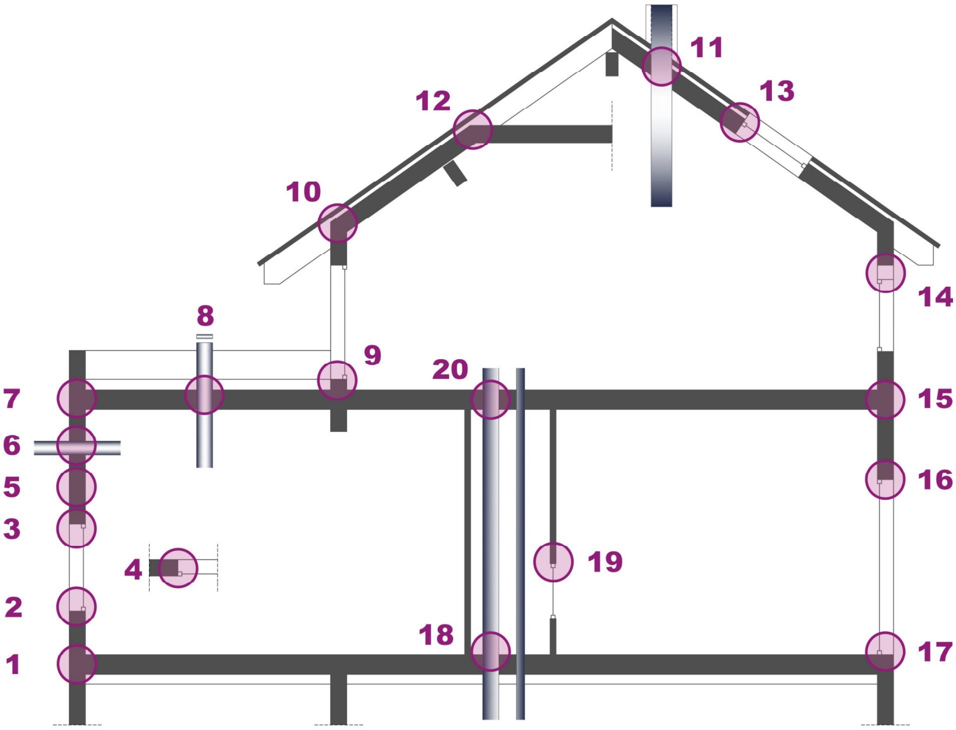


Figure 5. Vertical section of a typical building with identification of potential leakage junctions.

1 Junction lower floor / vertical wall
2 Junction window sill / vertical wall
3 Junction window lintel / vertical wall
4 Junction window reveal / vertical wall (horizontal view)
5 Vertical wall (Cross section)
6 Perforation vertical wall
7 Junction top floor / vertical wall
8 Penetration of top floor
9 Junction French window / vertical wall
10 Junction inclined roof / vertical wall
11 Penetration inclined roof
12 Junction inclined roof / roof ridge
13 Junction inclined roof / window
14 Junction rolling blind / vertical wall
15 Junction intermediate floor / vertical wall
16 Junction exterior door lintel / vertical wall
17 Junction exterior door sill / sill
18 Penetration lower floor / crawlspace or basement
19 Junction service shaft / access door
20 Junction internal wall / intermediate floor

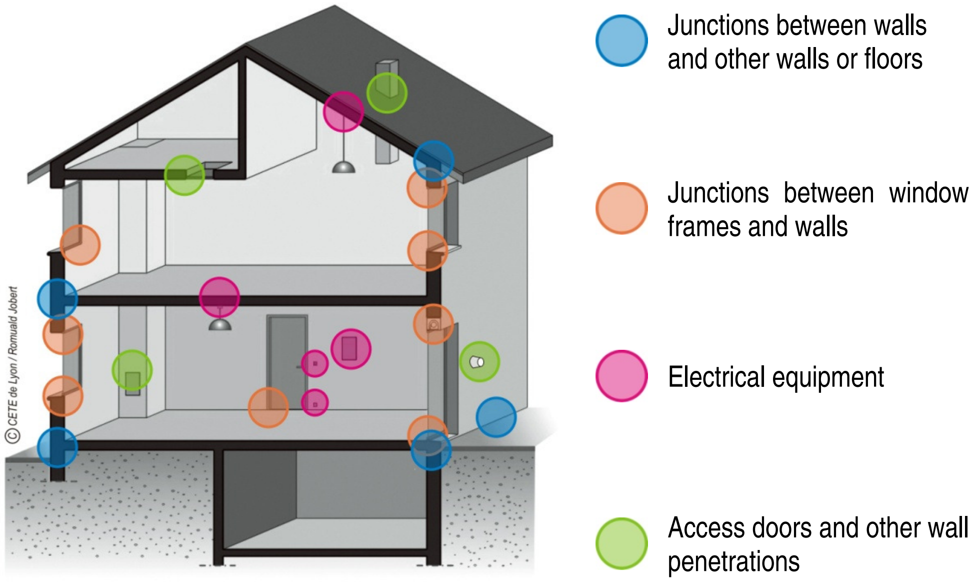


Figure 6. Common leakage sites classified in 4 categories.

2.4. Common traps

Notoriously difficult design options for airtightness should be avoided.

Aside from the issues listed previously in this chapter, there are several details that are known to be difficult to treat even with extreme care on site. We have listed those in this paragraph and included recommendations to overcome the problems raised.

Gypsum board ceiling

It is common to find gypsum board ceilings in residences or service buildings that are suspended with metal or plastic rods or spacers (Figure 7). Unless the rods are specifically designed for this, it should absolutely be avoided to perforate the vapour barrier with the rods: there are too many of them to ensure careful tightening around all rods.

The solutions below can be implemented:

- The preferred solution is to staple the vapour barrier on the wood frame if building design allows, and to screw the spacers on the wood frame. This way, the horizontal metal bars on which the gypsum boards are screwed can be attached to the spacers, leaving some space for electrical conduits for instance (Figure 8) ;
- Another solution is to attach the horizontal metal bars to the metal suspension rods, to glue the vapour barrier on the metal bars (e.g. with double-face tape) and then screw the boards on the metal bars. This solution proves to be effective with regard to airtightness but has three disadvantages: first, if an airtightness test is performed during the construction, it must be in pressurization mode to avoid peeling the vapour film off the bars; second, it forbids any hole to be

drilled in the ceiling; third, there is no space for electrical or other conduits to run (Figure 9);

- Airtightness can also be achieved with a membrane perforated by *specifically designed* suspension rods recently available on the market.

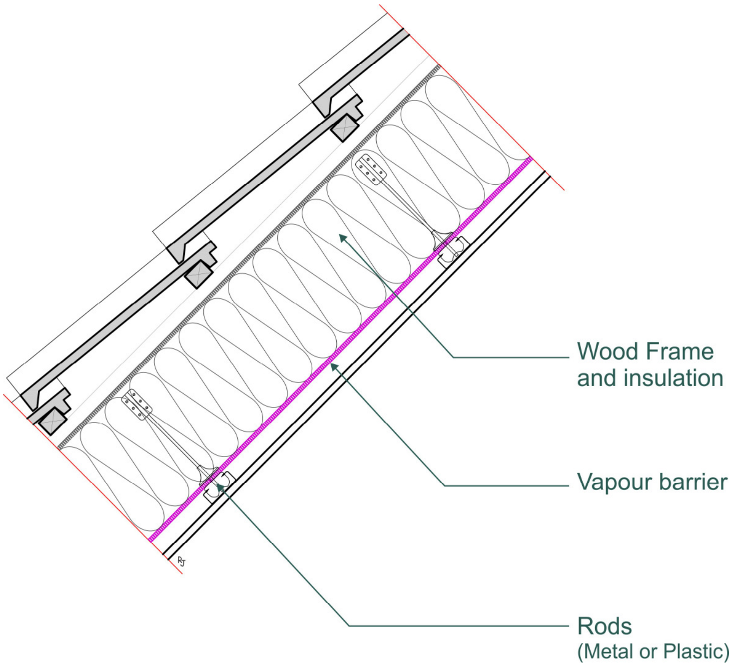


Figure 7. Rods perforating the vapour barrier behind a gypsum board ceiling. Unless the rods are specifically designed for this, it is very difficult to achieve good airtightness in this case.

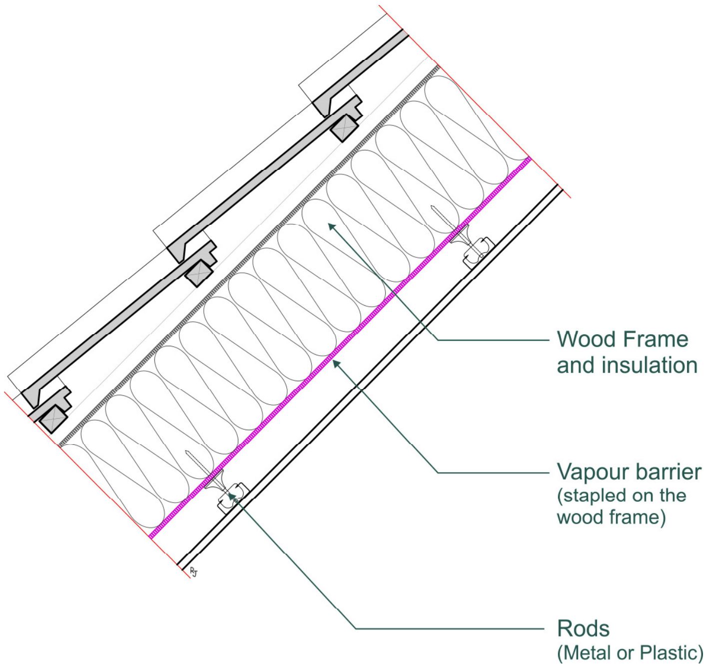


Figure 8. Possible solution to achieve airtightness behind a gypsum board ceiling. The vapour barrier is stapled directly on the wood frame.

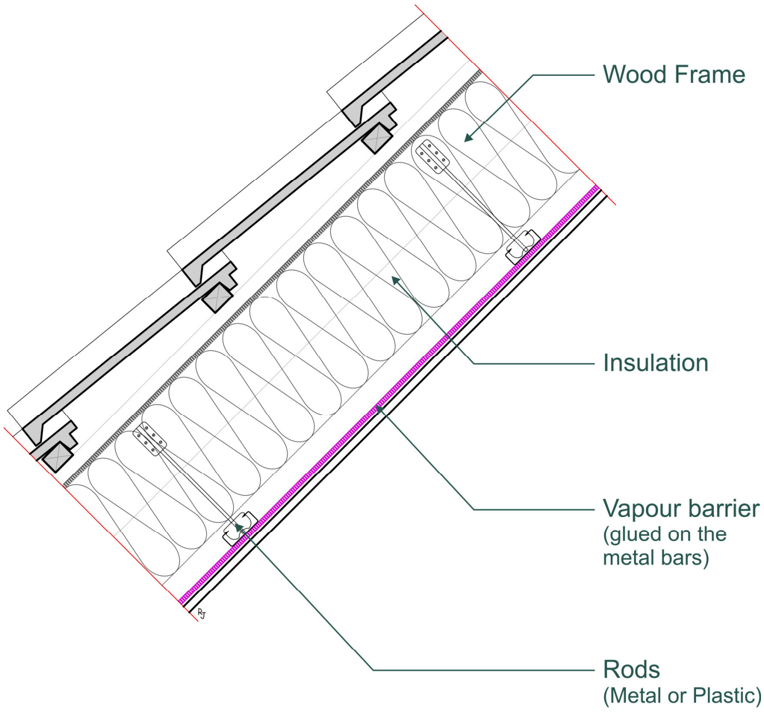


Figure 9. Possible solution to achieve airtightness behind a gypsum board ceiling. The vapour barrier is glued on the metal bars.

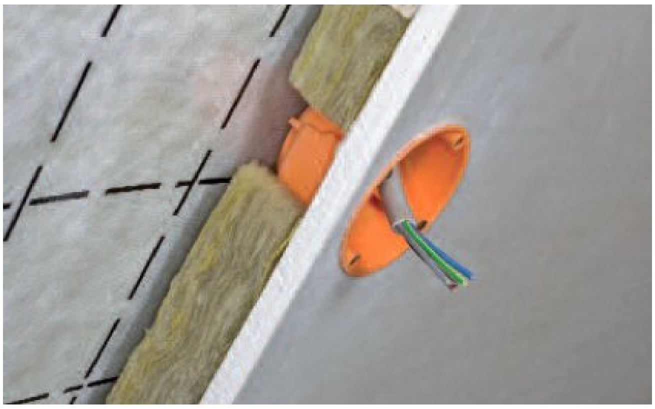


Figure 10. Space left behind gypsum board to allow electrical cabling to pass without perforating the airtight layer. Courtesy Isover.

Suspended ceilings

Suspended ceilings in service sector buildings are often made of tiles laid on a metal grid. On purpose, they can be lifted up to access the cavity where pipes, wires and ductwork is installed. Supposedly airtight designs with vapour barrier and insulation layers directly behind the suspended ceilings are bound to fail: by principle, the ceiling cannot be airtight as the tiles must come off easily; besides, there would be many perforations of the vapour barrier (at each rod suspending the metal grid). An additional shortcoming of this design (if the insulation layer is directly on the tile) lies in the heat losses through the ducts and pipes that run in an unconditioned space (Delp et al., 1998; Malmström et al., 2002).

In case of a suspended ceiling, the airtight barrier must be designed several decimetres away from the tiles. This allows the technical installations to be laid and maintained in the cavity without damaging the airtightness layer.

Floor joists

The continuity of the “skin” is notoriously difficult to achieve with joists laid on the vertical walls. Two common solutions are:

- To cut and tape the vapour barrier around each joist (Figure 11). This work requires patience and extreme care. The result is rarely excellent. In addition, it does not address the issue of vapour transmission through the joist;
- To wrap around the joist a weather protect barrier before it is installed, and to tape the wrapping to the rest of the vapour barrier (Figure 11). This solution may be slightly easier to implement than the previous, but remains unsatisfactory.

Besides, both solutions do not address the thermal bridge problem at this junction. A better solution is to design the floor so that the joists do not penetrate the vapour barrier. Figure 12 illustrates this option by hanging the joists on hooks. This is a thermal-bridge- and leak- free design as the insulation layer and vapour barrier are continuous. The designer should however check that provisions are made to solve noise and fire transmission issues.

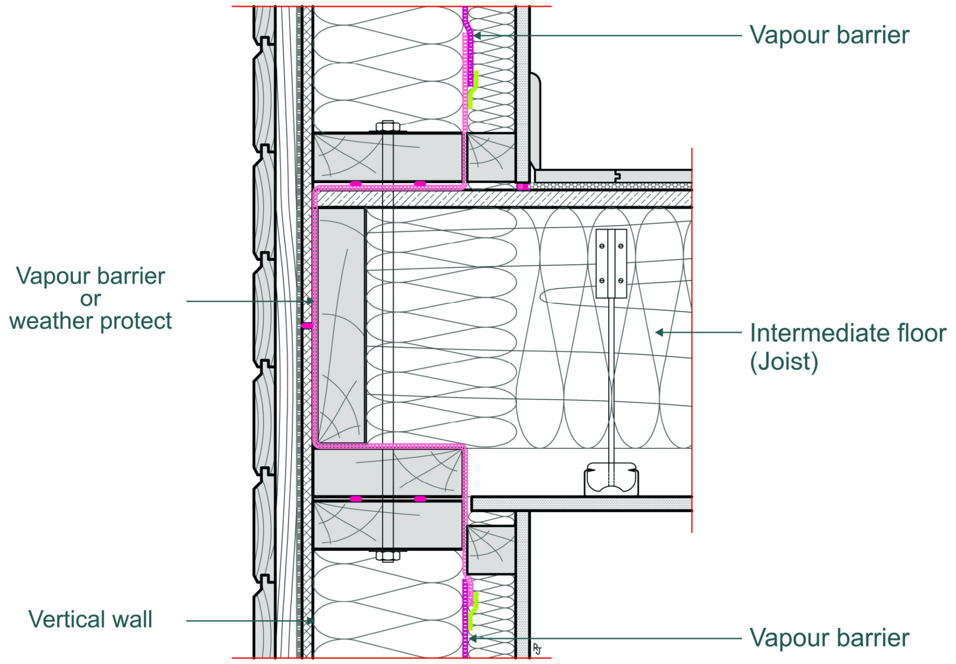


Figure 11. Common problematic airtight designs for floor joists.

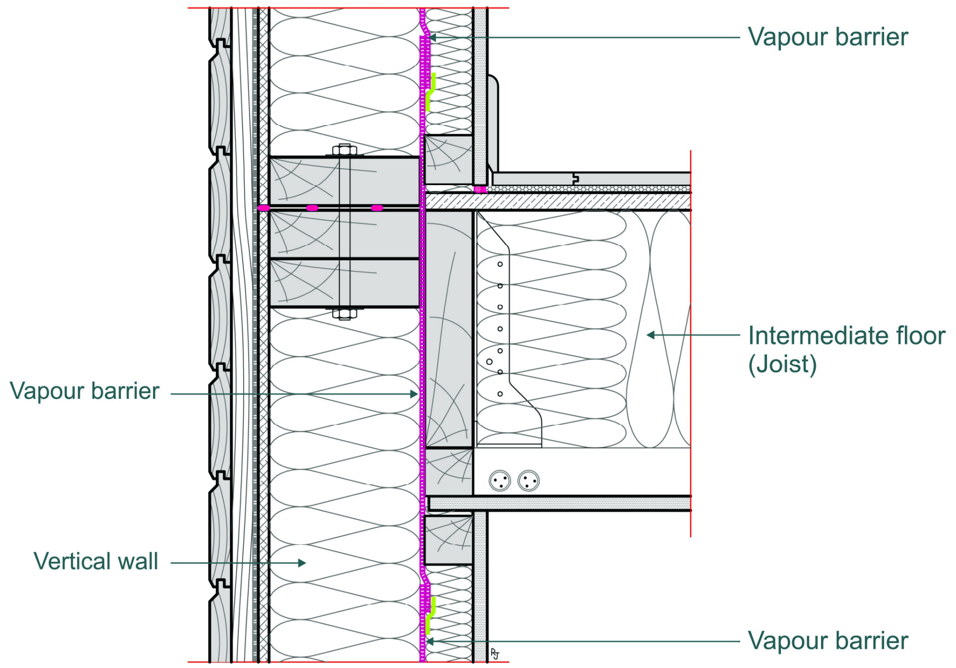


Figure 12. Thermal-bridge and leak- free design at floor joist.

Liquid water management and provision for air renewal are two key issues associated with envelope airtightness. The designer must carefully address those issues and take measures to avoid building damage or degraded indoor air quality.

3. Important precautions

Airtightness is clearly an important aspect for low-energy buildings; however, it is sometimes not well understood that it is part of a building design whose interactions between various features can be complex. To avoid problems, particular attention should be paid to:

- Liquid water management at the building level (water leakage treatment, capillarity), which implies also some thinking at a larger scale (run-off water);
- Provision for air renewal, which means that a natural, mechanical or hybrid ventilation system must be designed to extract indoor pollutants (including water vapour and flue gases if applicable) and that it must be compatible with the airtightness sought.

Run-off water should be driven away from the building facades with appropriate slopes and drainage strategy.

3.1. Run-off water

The designer should take measures to avoid run-off water to accumulate near the building facades. This requires to have a global view on the drainage of storm water at the neighbourhood scale and to define a strategy for the lot of interest. Appropriate slopes should allow surface water to be evacuated from the immediate surrounding of the facades, and thereby limit water capillarity issues or water leaks. This can be the opportunity make provision for storage in a water tank or pond away from the building (Figure 13).

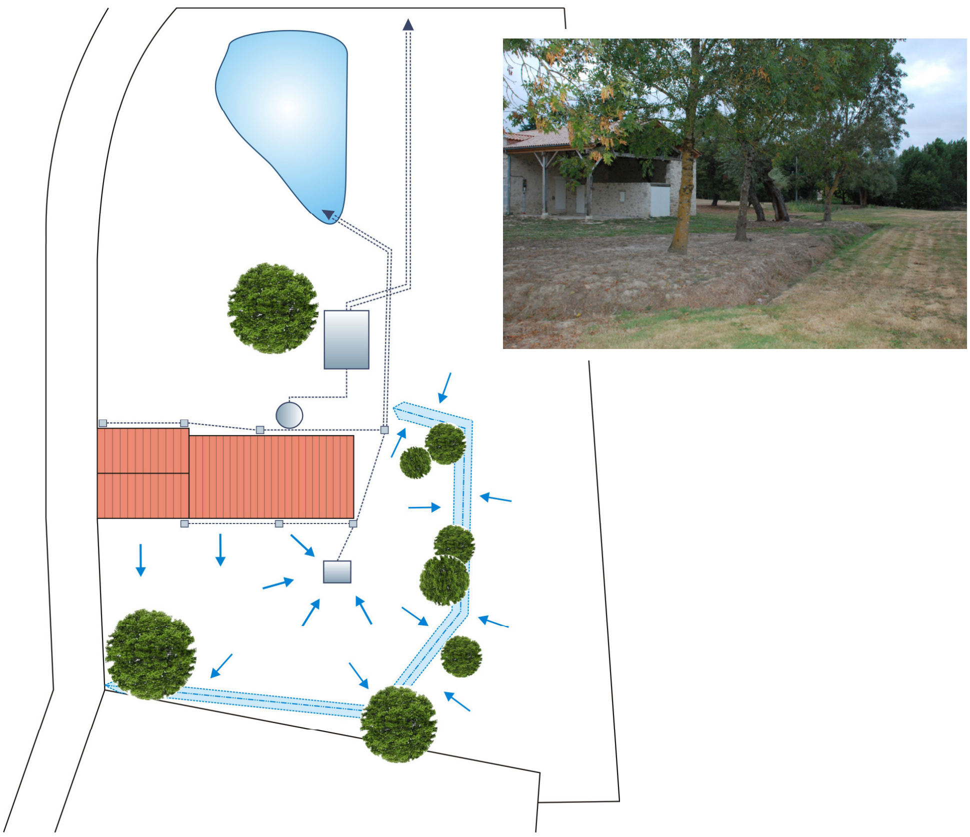


Figure 13. Example of a strategy implemented to keep run-off water away from a building.

3.2. Water leaks from walls and roof

The designer should take measures to avoid (and repair if applicable) water infiltration from through walls and roof.

While it is in general essential to avoid water leaks in the envelope, it becomes even more crucial with an airtight building as it will be harder for the water to escape. In case of renovation, a pre-requisite is to perform careful repairs of water leaks to obtain a perfectly watertight envelope. Where applicable, a rain screen can be useful for additional safety in case of tile failure, as well as to preserve the thermal resistance of the insulation layer which can be downgraded due to wind infiltration (Figure 15-Figure 14).

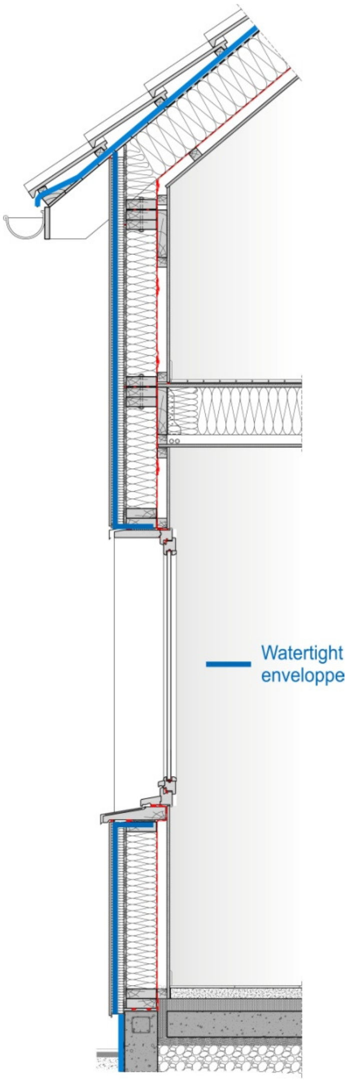


Figure 14. Schematic representation of watertight envelope.

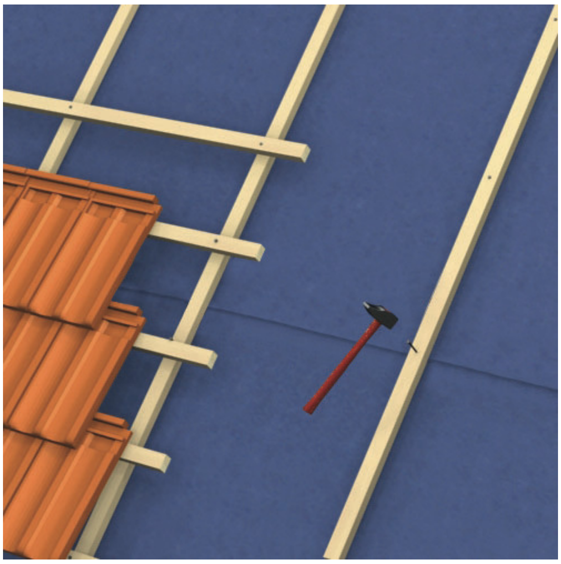


Figure 15. Installation of a rain screen. Courtesy Knauf Insulation.

While capillarity issues are generally well-documented and treated in new buildings, they are particularly important to address in building renovation.

3.3. Capillarity

Water can enter the envelope by capillarity, i.e., the ability for water to move up through porous building materials. Generally, this issue is not crucial in new constructions given their foundations and installation of capillary breaks. Design options for new buildings are well-documented. This problem is however essential in old buildings and aggravated with the absence of foundations and porous structures. To overcome this problem, the following actions can be envisaged:

- install a drainage system around the building. It will typically be about 1 m away from the façade to avoid weakening the structure, especially in the absence of foundation; and/or
- underpin the building and install a water barrier. This solution is similar to what is installed in new constructions, however, extreme care must be taken to avoid the collapse of the façade. This work is usually performed by portions.

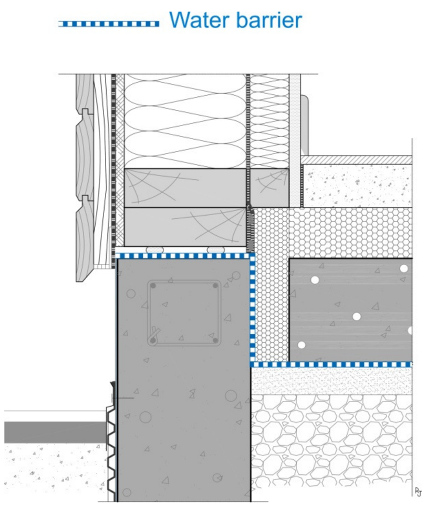


Figure 16. Water barrier.

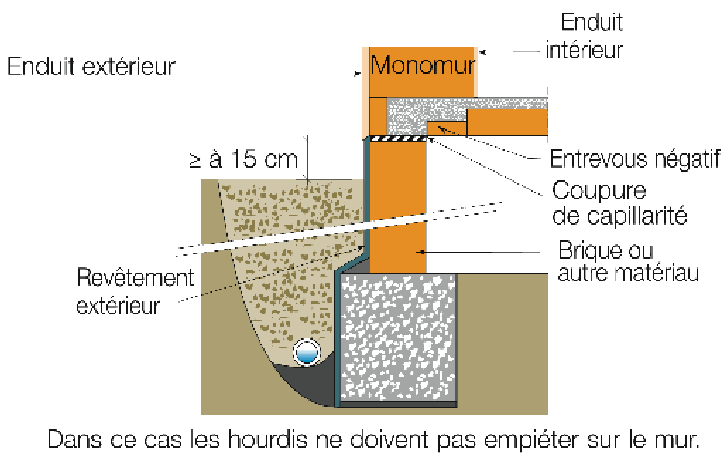


Figure 17. Drainage system. Courtesy Wienerberger.

Provision for proper air renewal is essential. Particular attention should be paid to the compatibility of the ventilation system with combustion appliances.

3.4. Compatibility with ventilation system

One or several natural and/or mechanical ventilation system(s) must be designed to extract indoor pollutants, including water vapour and flue gas. Evidence shows that the underlying design principles are not always compatible with an airtight envelope. One striking example lies in the case of combustion appliances with an indoor air intake. Although it is obvious that enough comburant (air) must be provided to the appliance, it is not uncommon to see such system installed ignoring this rule, potentially generating carbon monoxide (CO) emissions within the occupied zone. To avoid these kinds of problems, we recommend that the air intake or exhaust for all systems but the ventilation system do not interfere with the indoor air.

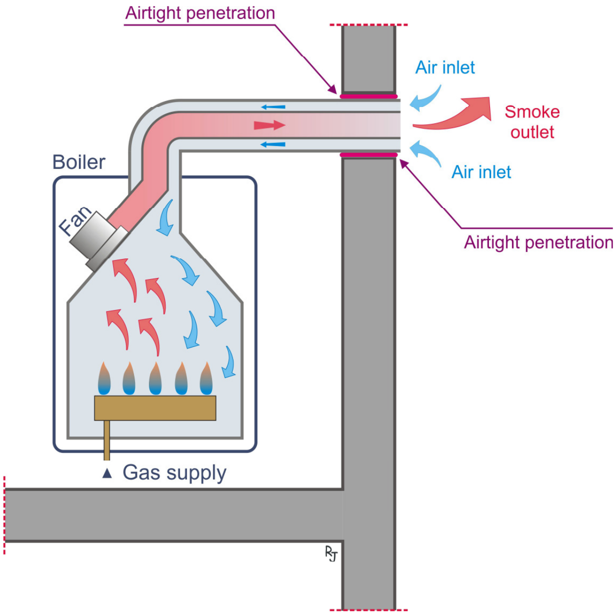


Figure 18. Boiler flue with outside air intake.

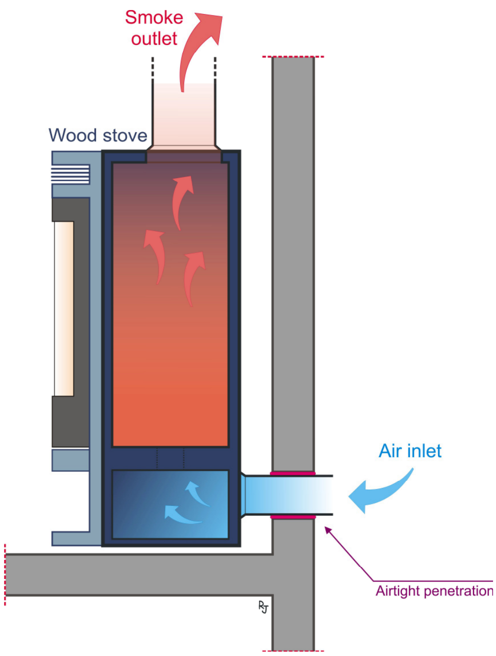


Figure 19. Airtight wood stove with outside air intake.

4. Tightening products

In this paper, the products are described in general terms, although there may be large differences between the physical characteristics of products falling under the same generic term (e.g. vapour barrier, silicone mastic, etc.).
Designers and installers should check on a case-by-case basis the compatibility of the products for their specific use.

The approach to design and install a continuous airtight layer system depends on the construction types; however, it is possible to define two common major steps:

- The treatment of opaque walls;
- The treatment of joints between building components and walls.

The designer should choose the appropriate tightening materials based on their specifications in terms of product compatibility, vapour diffusion properties, etc. Today, there is little information on the durability of these products, although there exist recent studies on this subject (Gross and Maas, 2011).

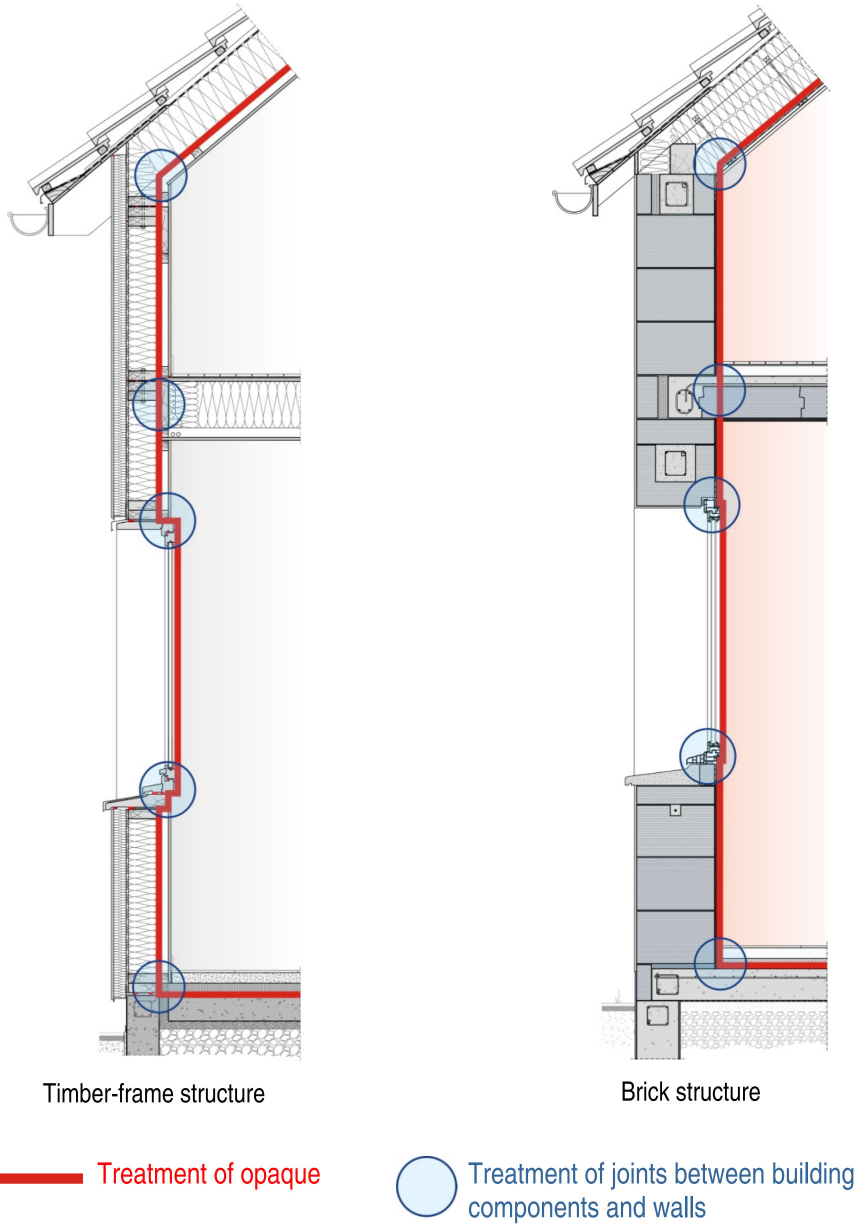


Figure 20. Distinction between the treatment of walls and joints between building components and walls.

The solution chosen for the treatment of the opaque walls is a first crucial step because it dictates the location of the weak points at joints that have to be treated. It represents the major part of the "airtight skin".

4.1. Treatment of opaque walls

The treatment of opaque walls consist in tightening large surfaces that are leaky either because they are porous or because they include a large number of discontinuities. There are two major ways to tighten these surfaces:

- Plasters are generally used for the heavy constructions made of masonry blocks in external insulation systems or low-U masonry blocks;
- Vapour barriers or retarders are dominantly used for dry constructions (e.g., timber-frame constructions) or internal insulation systems.

Plasters

Plasters are fluid or paste-like mixtures made of cement, lime, or gypsum. These products are spread or projected on the surface. The choice of the plaster should be based on:

- The hygrothermal behaviour of the finished wall, including the plaster and possibly additional coverings;
- The nature of the surface, in particular its compatibility with the plaster and surface grime;
- The location of the surface (e.g., whether it is exposed to rain or bumps);
- The methods and conditions for on-site implementation;
- The type of finish desired;
- The possible additional coverings.

Figure 21. Plaster applied on interior wall.

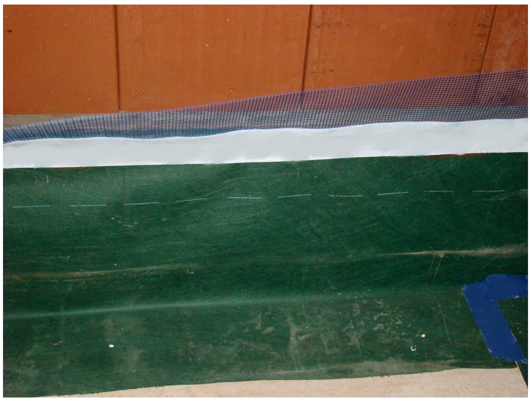


Figure 22. Non- adhesive membrane (glued on the vapour retarder) equipped with a grid to receive plaster against interior wall. Courtesy Wienerberger.

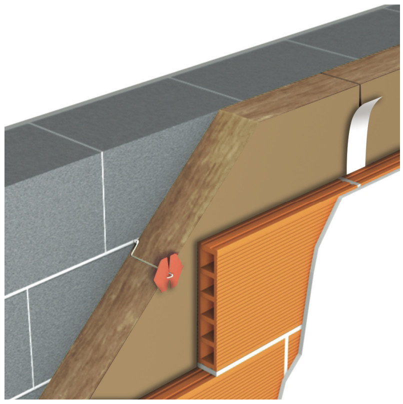


Figure 23. Example of application of a plaster on an interior wall. Courtesy Knauf Insulation.

Vapour barriers or retarders

Vapour barriers or retarders are membranes or films of large areas originally intended to limit or regulate vapour transfer within vertical walls and roofs. When properly installed and at the right location[3], they prevent interstitial condensation, namely in the insulation layer. Their composition can be very diverse, e.g. they can be partly made of polyethylene, polyester, polyane, aluminium, etc.

The membranes are also airtight (unless perforated) and therefore can be used to form the airtight "skin" mentioned above (see Figure 2). It is important to take provisions to avoid numerous perforations of the membrane which will be tedious if not impossible to tighten efficiently afterwards. The designer must see that:

- The membranes cover the entire external surface of the conditioned volume;
- The rolls are directly stapled or glued the metal or wood studs or to the roof structure;
- The rolls should not have wrinkles when installed and must overlap (an overlap of 5 cm is often recommended as a minimum);
- There should be some clearance at the joints with the structure to absorb the movement of the structure with time;
- The rolls should be glued between themselves with an adhesive band.

[3] The vapour barrier or retarder should be located so as to limit vapour transfer through the wall prior to the temperature decrease. For most residential and office building applications in European climates, it is located on the inside, prior to the insulation layer. It is recommended to perform a condensation risk analysis, e.g., based on a Glaser diagram, to prevent condensation with proper design and materials (e.g., vapour diffusion resistance).

4.2. Treatment of joints between opaque walls and other building components

Joints between opaque walls and other building components are generally sealed with either:
- pre-compressed impregnated foams;
- adhesive membranes and tapes;
- extruded mastics;
- closed-cell expanding foams; or
- specific sealing products.

One common requirement for these products is that they must be flexible enough to absorb building stress without cracking.

Each joint between the opaque walls and the other building components has to be tightened. This includes joints with other opaque walls, windows, building structure components (e.g., beam, floor joist), doors, ducts (e.g., for a ventilation system, an exhaust hood, or a combustion appliance), pipes, electrical conduits or cables.

The designers and workers must keep in mind the principle of continuity of the airtight skin at these joints.

Pre-compressed impregnated foams

The products that are used are polyurethane or polyester foams impregnated with a synthetic butyl or acrylic resin.

The foams are presented as rolls a few centimetres wide. Their thickness is reduced when rolled-up, but they get thicker more or less rapidly as they are installed. The retarded decompression process allows the gaps to be filled nicely while the foam was put without force into them. It is particularly useful for window installers when the windows are placed within the wall structure as the window can be adjusted before decompression occurs. This also prevents the foam from sliding and rolling while it is placed within the wall structured.

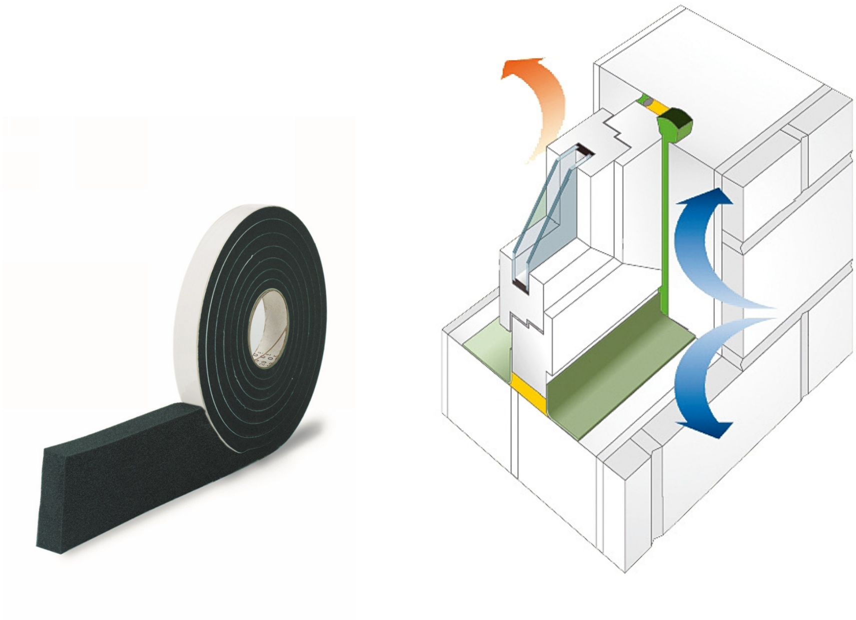


Figure 24. Pre-compressed foam. It gets thicker slowly when unrolled to allow the worker to put it in place and adjust the window before the full decompression occurs. Courtesy Tremco illbruck.

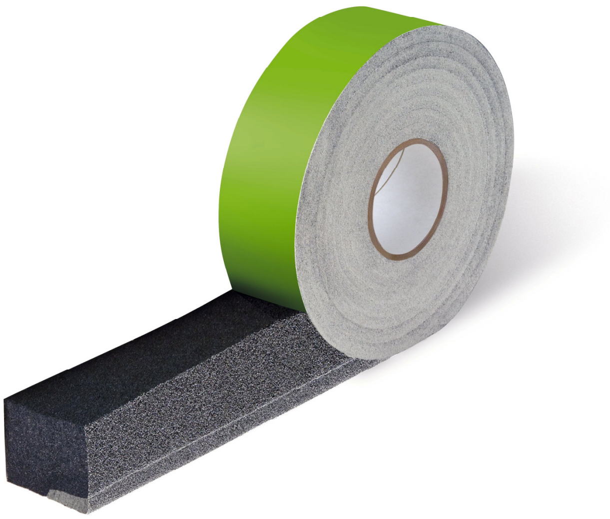


Figure 25. Multi-functional pre-compressed foam. Its size and design prevents air and water infiltration on both sides of the window or door as well as thermal insulation. Courtesy Tremco illbruck.

Adhesive membranes and tapes

Adhesives membranes seal joints between the peripheral of a window and a vapour barrier or retarder or a plaster.

These membranes are flexible. They generally consist of a polyethylene film associated with a nonwoven fabric with:

- on one side, an adhesive tape, single or double-face, that is glued to smooth surfaces (wood, aluminium, PVC). If the membrane is not equipped with an adhesive tape, the installer can use an extruded mastic;
- on the other side:
    - either an adhesive tape (e.g., butyl-based to adhere on porous surfaces such as concrete or masonry blocks); or
    - a polyester or fibre glass grid that can be covered with a plaster.

Figure 26. Application of a membrane around a window. Courtesy Soudal

Adhesive tapes seal junctions between similar building elements. They are often used in three cases:

- To seal Orientated Strained Boards (OSB) or other wood panels in timber-frame constructions;
- To glue two adjacent rolls of vapour barrier or retarder;
- To seal a film on a non-mineral smooth surface (wood elements and panels, PVC) or a smooth metal surface.

Depending on the application, the tapes can be rigid or flexible. They are made of a paper or nonwoven textile (polyethylene or polypropylene) support. The surface where the tape is glued must be clean, dry, grease- and solvent-free for a good adhesion. A primer can be used in some cases to increase adhesion.

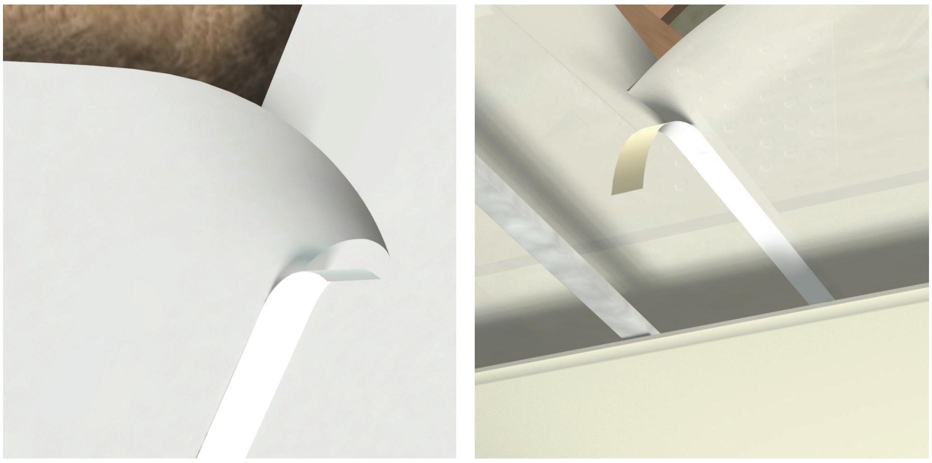


Figure 27. Use of a tape on a vapour barrier. Courtesy Knauf Insulation.

Figure 28. Plasto-elastic butyl rubber adhesive / sealant applied to one side of an aluminised polyester film. Courtesy Tremco illbruck.

Extruded mastics

These products can fill small gaps (about 10 mm maximum). They are generally packaged in cartridges that can be used in a regular caulking gun.

There exits a wide range of mastics based on “hybrid”, polyurethane (PU), silicone, butyl or acrylic. Acrylic-based mastics should be used for interior use and finishing only, while other mastics can be used outdoors with some precautions. Butyl mastics provide excellent adhesion to most surfaces but have limited elasticity and are solvent-based. Most silicone mastics provide excellent airtightness with glass and metal and are UV-resistant, while PU mastics adhere very well to most surfaces, but are more UV-sensitive than silicone. Paint can be applied on PU mastics, which can help protect the joints. “Hybrid” sealants[4] are claimed to combine the strength of polyurethanes with the weathering resistance of silicones.

[4] The terminology used for these sealants is confuse. They are sometimes referred to as Silyl Modified Polymers (SMP) or MS polymers for instance.

ISO 11600 proposes a classification for glass (G) and construction (F, standing for "façade") sealants based on end-use (F or G), movement capability, elasticity, and modulus for an appropriate choice depending on the application (BASA, 1999).

Mastics alone should not be used to fill large deep gaps. For this, a back-up material (or backer rod) can be installed simply to limit the depth that has to be filled with the mastic. Generally, it has a square or circular section and is made of polyethylene closed- or open-cell foams.

The use of a backer rod is also recommended:
- to provide a backing against which the sealant is applied, forcing the sealant to the sides of the joint;
- to prevent 3-sided bonding (which would be detrimental to the joint functioning and longevity) since the mastic does not adhere to the backer rod.

Figure 29. Closed-cell PE round backer rod. Courtesy Soudal.

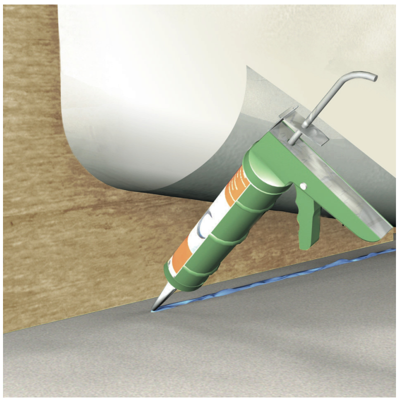


Figure 30. Application of sealant with caulking gun. Courtesy Knauf insulation.

Expanding foams

Expanding foams recommended for airtightening are generally elastic PU-foams. Elasticity is an important requirement for these foams so that the junction remains airtight with time. Rigid foams will crack as the building structure ages. Dry foam should not be cut to avoid deterioration of its airtightness properties and stability.

In air sealing applications, these foams are used primarily at the junction between the windows and the walls.

Figure 31. Application of elastic PU foam around a window. Courtesy Soudal.

Specific sealing products

In addition to the materials and products listed above, there are products for very specific applications. These include:

- Pipe, duct or cable rubber grommets

These products allow one to create an airtight seal around circular-section elements such as plumbing pipes, electrical conduits or cables as these pass through the airtight layer.

There exists an array of products for diameters ranging from a few millimetres up to 355 mm.

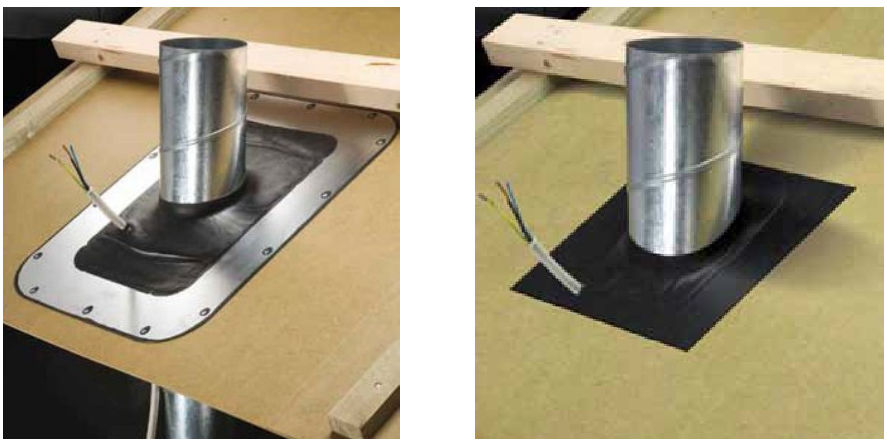


Figure 32. Self adhesive membrane grommet. For sealing building components which penetrate the roof or wall construction and/or the vapour barrier. Courtesy Lindab.

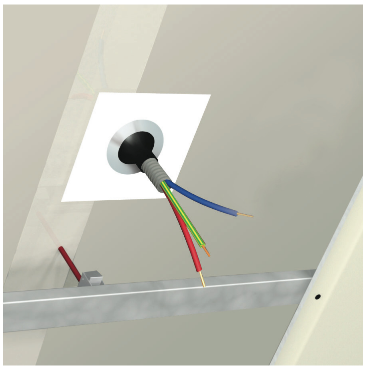


Figure 33. Grommet for electrical penetration. Courtesy Knauf Insulation.

- Repair tapes

These are typically used to repair holes in films or holes made on purpose for blowing insulation. They can be packaged as oversized tape rolls or flat patches.

- Airtight electrical boxes

These are flush-mounted airtight boxes with flexible parts that stay airtight when perforated by an electrical cable, wire, or conduit. If conduits are used, there are two options:

- The conduits are airtight between two parts of the conditioned space; or
- The conduits are sealed, for instance, with a cap that stays airtight when perforated with the electrical wires, to prevent air from flowing through the conduit to the outside.

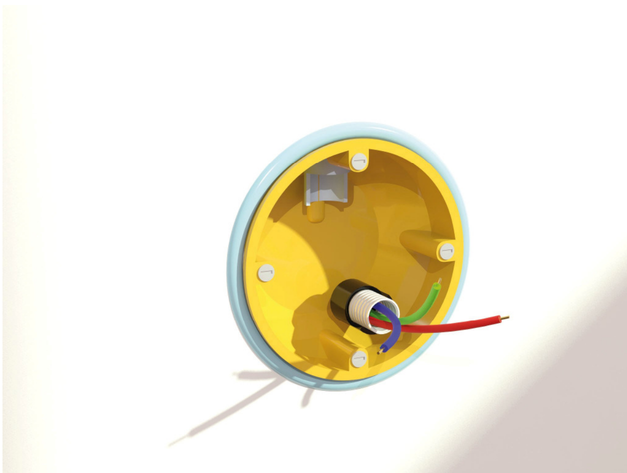


Figure 34. Illustration of an airtight electrical box. A cap may be needed to prevent air infiltration through the conduit. Courtesy Knauf Insulation.

Conclusion

Envelope airtightness clearly represents a major challenge towards the generalization of nearly zero-energy buildings in new constructions and renovation. There are many technical and organizational issues to deal with, and todays' observations and field campaigns suggest that there is significant room for improvement to overcome these challenges.

The good news is that there are methods and products readily available to build airtight. There are both:

- Solutions that have proved to be very effective for a number of years already (about 20 for some), in particular in pioneering very low-energy buildings projects; and
- Fairly new approaches and technical solutions emerging thanks to the considerable RTD efforts of research bodies, technical centres and industries.

Especially with the latter, there are many areas that merit further investigation, for instance with regard to cost and durability, ventilation/infiltration/indoor air quality interactions.

One major barrier resides in the opposition between on the one hand the profound changes that are needed to build airtight in the design options and solutions implementation of nearly all building workers; on the other hand, the weight of tradition in the building sector. Therefore, we expect that the market transformation towards airtight buildings in any country willing to implement a wide-scale policy on this issue will be a long process, although the market uptake of labels such as PassivHaus, Minergie-P or Effinergie for instance in some regions brings optimism. Good training and dissemination are two important keys to achieve this goal.

References

BASA. 1999. The BASA Guide to the ISO 11600 Classification of Sealants for Building Construction. British Adhesives and Sealants Association. 10 pp. Available at http://www.basaonline.org

Delp, W. W., Matson, N. E., Tschudy, E., Modera, M. P., and Diamond, R. C. (1998a). Field investigation of duct system performance in California light commercial buildings. ASHRAE Trans. 104(II) 1998, TO-98-8-1.

Dorer, V., Tanner, C., Weber, A. 2004. Airtightness of buildings. AIVC VIP 08. Available at www.aivc.org.

Geving, S., Holme, J., Uvsløkk, S. 2010. Alternative dampsperrer med uttørkingsmulighet mot innelufta. SINTEF Byggforsk. Report n° 65. Available at http://www.sintefbok.no.

Gross, R., and Maas, A. 2011. Quality assurance for adhesive-based joint technology in the design of airtight layers. Proceedings of the BUILDAIR Symposium. Berlin, 15 May 2011.

Langmans, J., et al. 2009. Potential of using windbreakers as air barrier in light weight constructions. Proceedings of the 4th BUILDAIR symposium – 30th AIVC conference. Berlin, 1-2 October 2009. pp. 44-45.

Malmstrom, T., Andersson, J., Carrié, F.R., Wouters, P. Delmotte, C. 2002. Source Book for Efficient Air Duct Systems in Europe. SAVE AIRWAYS. 95 pp. Available at http://www.inive.org

MININFIL. 2010. Towards airtight new and existing buildings. A project within the PREBAT Programme. Project n° 0704C0175, duration: 12/09-12/10. www.cete-lyon.developpement-durable.gouv.fr

Schnieders, J. 2003. CEPHEUS – measurement results from more than 100 dwelling units in passive houses. Proceedings of the ECEEE summer study. pp. 341-351.

Van Orshoven, D. 2010. Summary of the recommendations of the ASIEPI project. Information paper P191. Available at www.asiepi.eu.

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