THE 10 STEPS TO CONCEIVE AND BUILD AIRTIGHT BUILDINGS

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ABSTRACT

Airtightness becomes a more and more important parameter in the rationalization of the energy consumption. The quality of the works during the construction process is essential. However, this particular step is on itself absolutely not sufficient to build airtight buildings. Airtightness has to be taken into account from the pre-project. For that, architects have to deal with a large bunch of items. Steps as the definition of the ambition level, the precise positioning of the airtightness barrier into the building are essential. Possible contradictions with permanent ventilation requirements have to be taken into account. For instance, in Belgium, there are natural ventilation requirements for fire safety reasons or for open heating devices (as stoves) and it could be difficult to conciliate these requirements with the performance of airtightness. In addition, some equipment such as distribution board must be adequately placed to avoid some air leakages. At last, the choice of equipment types and their position could be crucial to achieve the airtightness level considered. The construction process on itself, intermediate blower door tests during the construction process, the final blower door test as well as the attention points during the occupancy have also to be taken into account.

Thereby, a path of 10 steps starting from the very beginning of the conception up to the utilization of the building have been identified to facilitate the realisation of affordable airtight buildings.

KEYWORDS

Airtightness of buildings, fan pressurization test, conception, Belgium, air permeability class

1 INTRODUCTION

Airtightness becomes a more and more important parameter in the rationalization of the energy consumption. The quality of the works during the construction process is essential. However, this particular step is on itself absolutely not sufficient to build airtight buildings. Airtightness has to be taken into account from the pre-project. For that, architects have to deal with a large bunch of items. The present paper proposes a path decomposed on 10 practical steps to support the architect in the design and the build of an airtight building. The 8 first steps refer to the conception itself and must be carried before the start of the construction site. The exact contain of each step depends on national norms or regulations but the general path could be applied in every country.

2 THE 10 STEPS

2.1 Step 1: Define the ambition level

Currently in Belgium, there is no requirement regarding the airtightness in the EP regulations. But this criterion is taken into account into the EP calculation for new buildings. Without pressurization test, a default value is applied. This v50 default value is equal to 12 m³/(h.m²) for the calculation of the heating consumption. The ambition level is generally chosen by the customer.

Belgium consists of three regions which are independently responsible for the rational use of energy in buildings on their territory. The three regions are: the Flemish Region, the Walloon Region and the Brussels-Capital Region. Recent information indicates that the average air permeability (v_{50}) is 2.9 m³/(h.m²) in the Walloon Region and 3.7 m³/(h.m²) in the Flemish Region.

In any case, the targeted value of airtightness should be fixed as soon as the pre-project. This value should have an impact on the first choices of the architect. The different steps of the process are all important but may be crucial if the airtightness level is severe.

2.2 Step 2: Define the airtight zone within the building – The protected volume

From the first stage of the draft, the architect should define and keep in mind the protected volume. The protected volume is defined in the Energy Performance of Buildings regulations as the volume including all heated spaces (and/or cooled) directly or indirectly, either continuously or intermittently, within the considered building. The architect must know the way that the pressurisation test will be realized in that building and which part of the building is involved by the ambition level of airtightness. He should also check the consistency between the thermal insulated volume and the airtight volume.

2.3 Step 3: Choose equipment types and their position regarding the airtight zone

Many technical appliances are integrated into our buildings, whether for heating, ventilation, gas distribution, electrical and telecommunication, active cooling system, ...

Most of the rooms including these technical installations require direct outside air, e.g. for combustion purposes.

A representative example of this step's issue concerns the heating appliance. Belgian standards require natural ventilation for the technical room including open heating devices. Non-sealable openings through the outside must be provided for air supply and to evacuate

the combustion gases. These openings have a significant impact on the airtightness of the building. Indeed, for a single-family house of 500 m³ (interior volume) with an open heating device type B (25kW) in the protected volume, the required openings lead to an increasing of 2,4 h^{-1} of the ACH50. Thus, the use of this type of device is not recommended within the protected volume. If such kind of heating system is chosen, architects should forecast an installation space outside the protected volume.
However, room sealed appliance doesn't require openings through the envelope. The architect should privilege room sealed appliance and should place the installation space in the protected volume.

Thus, for heating device and for other appliances, it is possible to conciliate fire safety, ventilation requirements and airtightness by choosing appropriate equipment and by positioning them relative to the protected volume. These decisions have to be taken early enough in the process of conception.
These choices are dependant to the norms and regulations of each country. In Belgium, summary tables are available as tools for designer. One of this tables is given below as example.

Table 1: Examples of advices for equipment positioning relative to the airtight zone

Equipment / rooms	Recommended position
Garages	Foresee specific ventilation system or place them outside the protected volume
Technical shafts	Depending on the fire regulations. If not applied in the considered building: inside the protected volume If applied in the considered building: outside the protected volume or provide a partitioning of the shafts
Elevator shafts	Inside the protected volume and provide a ventilation system with motorized valves Or Outisde the protected volume
Counters gas	Outside the protected volume

2.4 Step 4: Place piping and ducts

The architect should place piping and ducts in order to minimize the openings through the airtight envelope. He also should try to keep ducts in the protected volume.

2.5 Step 5: Choose the good material to achieve an airtight envelope

We could consider a material as airtight if its air permeability is below 0,1 m³/(h.m²) for a pressure difference of 50 Pascal. This criterion could be useful to choose wood panel, for example. In Belgium, plaster (generally at least 12mm) is traditionally used on the inner surface. Laboratory tests have shown that the air permeability of this kind of product whatever the masonry is below the limit value. Recent research[1] has studied the initial air permeability performance of different types and thicknesses of plaster and their durability.

[1] The research project DREAM funded by the Walloon Region (Belgium) investigates the durability of air barrier by testing them in laboratory. A paper on this project is available: "Assessment of the durability of the airtightness of building elements via laboratory tests"

2.6 Step 6: Correctly choose doors and windows

Doors and windows are one of the only building components whose the airtightness performance is tested in laboratory. These tests are realized for CE marking reasons and are realized according to European standards. The architect should privilege a class 4 air permeability. However, in some cases of high level of ambition, it could be not enough efficient.

An analysis of 300 windows tested in the laboratory of the BBRI (2008-2009) shows that 87% of tested products corresponding to the class 4, whatever the material of the frame. Therefore, a subdivision of the class 4 seems needed to help architects and builders choose the most appropriate product.

A subdivision of the class 4 into two supplementary classes (5 and 6) illustrated by the figure 1 will be proposed to the Committee for Standardization (CEN).

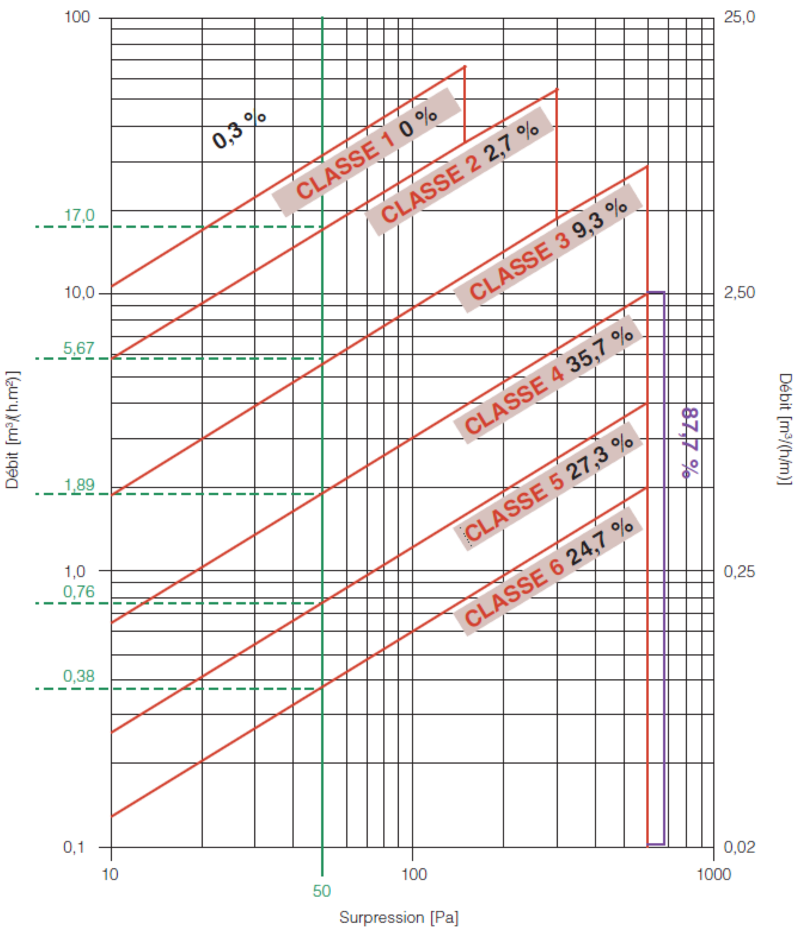

Figure 1: Distribution of tested windows between different classes of air permeability

Currently, to achieve high airtightness level and without classes 5 and 6, it is recommended to ask the test report and estimate if the air permeability is compatible with the ambition level of the considered project.

2.7 Step 7: Prioritize the constructive nodes

To guide the designer, the path includes tables giving an indication of the potential leakage if constructive nodes are not properly treated. These tables have been developed during the research project Etanch'air. One of its goals was the quantization of common air leakages.

This kind of table is useful for the designer in order to identify the priorities he has to give to different constructive nodes.
Note that these priorities should be considered depending upon the construction system of the project, its geometry and its level of ambition. The cavity wall example, the mainly used constructive system in Belgium, as well as the timber frame construction system are presented in the next tables.

Table 2: Illustration of the priorities

Prioritization order	
****	Priority 1
***	Priority 2
**	Priority 3
*	Priority 4

Table 3: Prioritization of the constructive nodes to be treated – Cavity walls

Constructive nodes	**Priority**
Ground bearing floor	* → **
Junction between separating wall and façade	*
Junction between flat roof and façade	*
Junction between intermediate floor and façade	**
Pitched roof: Purlins	*** → ****
Pitched roof : Gable	****
Pitched roof : Eaves	*** → ****
Pitched roof : Separating wall	*** → ****
Service penetration through roof	***
Junction between window and façade	** → ***

Table 4: Prioritization of the constructive nodes to be treated – Timber frame

Constructive nodes	**Priority**
Ground bearing floor	****
Junction between separating wall and façade	*** → ****
Junction between intermediate floor and façade	*** → ****
Pitched roof: Purlins	*** → ****
Pitched roof : Gable	*** → ****
Pitched roof : Eaves	*** → ****
Pitched roof : Separating wall	*** → ****
Service penetration through roof	***
Junction between window and façade	** → ***

2.8 Step 8: Choose technical solutions for each constructive nodes

A library of construction details in linked to the proposed path. An example is given with the figure 1 illustrating the treatment of a junction between façade and floor with an airtight membrane.

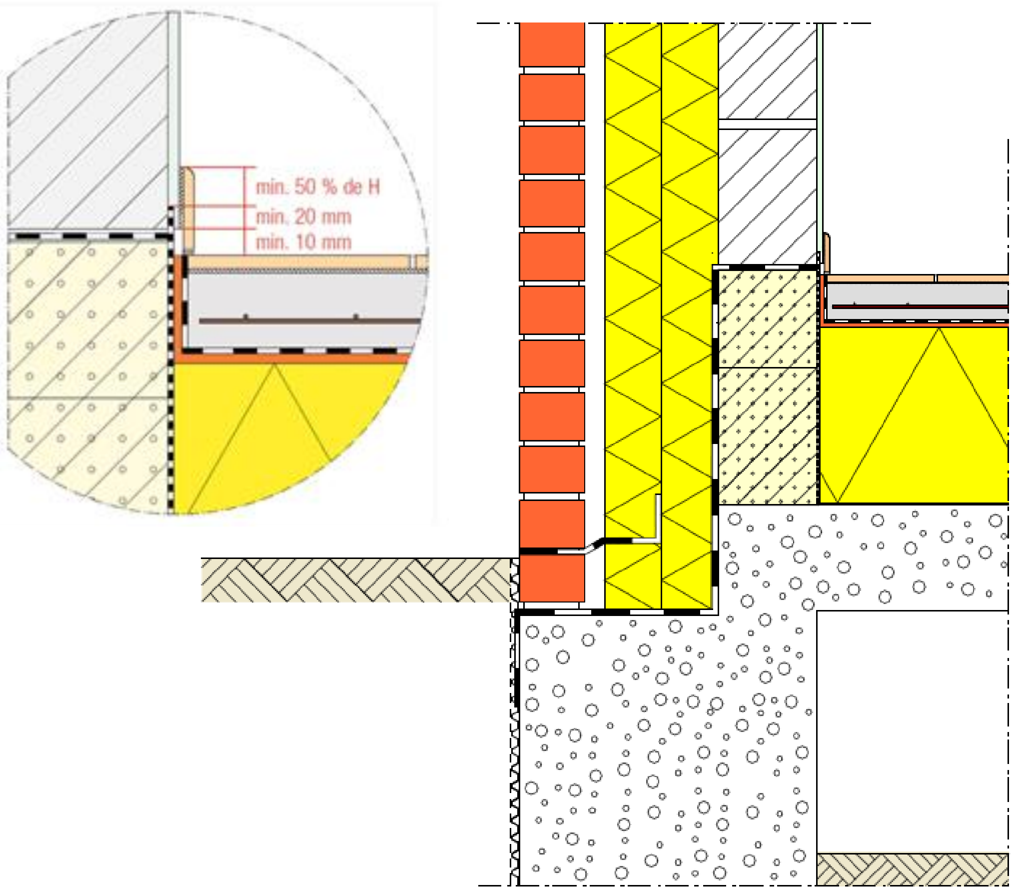

Figure 2: Illustration of a technical detail: junction between façade and floor using airtight membrane

Most of the time, several solutions are possible to resolve the nodes. Thus, a comparative table is proposed to support architect or builder in their choice. The following table compares three technical solutions available to treat the junction between façade and floor. This comparison is qualitative and uses three criteria: initial performance, implementation issue and durability. In the proposed path, each solution is illustrated by a construction detail or a picture.

Table 3: Qualitative comparison between different technical solutions for the junction between façade and floor.

	Initial performance	**Implementation issue**	**Durability**
No specific treatment	Good if the vertical joints of the masonry are properly filled	Importance of filling vertical joints	Possible cracks due to the building movements
Junction made with airtight membrane (figure 1)	Very good	Risk of significant damage to the membrane during construction	Junction products could be better in terms of durability for this node
Junction made cementing	Very good	Easy implementation	Possible cracks due to the building movements

2.9 Step 9: Check the coordination and communication between all the builders

Each involved builder has to be informed about the targeted value of airtightness, the protected volume and the nature of air barriers. The constructive details elaborated by the architects should be given to the concerned people as soon as possible.

2.10 Step 10: Provide an intermediate pressurization test

This intermediate test realized during the construction is highly recommended especially if the ambition level is important. The exact moment of the test will be chosen in order to be able to correct leakages that would be detected (e.g. when airtight layers are still accessible in roofs). The architect (of the builder) should plan it. A final test has of course also to be planned.

3 CONCLUSIONS

To achieve an airtight building, architects have to deal with a large bunch of items. Steps as the definition of the ambition level, the precise positioning of the airtightness barrier into the building are essential. Possible contradictions with permanent ventilation requirements have to be taken into account. In addition, some equipment such as distribution board must be adequately placed to avoid some air leakages. At last, the construction process on itself, intermediate blower door tests during the construction process, the final blower door test as well as the attention points during the occupancy have also to be taken into account.

Thereby, a path of 10 steps starting from the very beginning of the conception up to the utilization of the building have been identified to facilitate the realisation of affordable airtight buildings. The goal is to use these steps as a daily tool by the architects.

4 ACKNOWLEDGEMENTS

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