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ASSESSMENT OF THE DURABILITY OF THE AIRTIGHTNESS OF BUILDING ELEMENTS VIA LABORATORY TESTS

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ABSTRACT

The airtightness just after the end of a building phase is assumed to be relevant criteria for high energy performance. Testing on site the initial performance of the airtightness via the blower door test has become nowadays a common practice. This test is generally realized at the end of the construction works. What about the influence of ageing on the airtightness? Many questions exist on the durability of this initial performance. Even if retesting a building a few years after the initial test can provide a general view on the evolution of this performance, this could generate adding cost and couldn't give information on the origin of potential changes. Another approach may be to validate technology and building technics as sustainable solutions. In order to quantitatively evaluate the durability of the airtightness of building elements as well as building technics, a research realized in Belgium has tested in laboratory the initial performance of more than 50 building walls and their materials.
This performance has afterwards been tested after an accelerated ageing process including a.o. exposure to wind cycles (storms) corresponding to 10, 25 and 40 years of lifetime. The paper presents the main results of this research and points out the principal recommendations to guarantee the sustainability of this performance.

KEYWORDS

Durability, Airtightness, Building Technology

1 INTRODUCTION

Even we focus more and more on the airtightness of the new building to reach high energy standards, a lot of questions are still remaining targeting the sustainability of the performances. As of now, the blower door test confirms the initial airtightness just at the end of the building phase. This test will not provide any information on the long term performances of the airtightness. To consider the sustainability of the airtightness we should use some different ways.

The monitoring of the performances may cost and is intrinsically not a quality guarantee but only a control. But it’s more efficient to be proactive and to choose combinations of products which will therefore ensure the durability of these performances.
The research project conducted from 2012 to 2013 by the Belgian Building Research Institute in partnership with the University of Liège has targeted the basic criteria and useful technologies insuring the durability of the airtightness.
This article will not analyse all the results of the research but provide the important learnings from the research.

2 THE « DREAM » RESEARCH PROJECT

The research project called “DREAM” aims to evaluate and improve the durability of the airtightness of buildings quantifying the airtightness performance of different materials before and after ageing for 46 different walls (divided into 4 families).
Four different families of system ensuring the airtightness have been targeted in this project.

- Walls of blocks / bricks whose airtightness is ensured by coatings/plastering. Seventeen different walls were analysed in this family (inside plastering or outside coating);
- Walls whose airtightness is ensured by wood panels. Eleven different walls were analysed in this family
- Walls whose airtightness is ensured by a membrane. Eleven different walls were analysed in this family;
- Walls composed by industrialized systems (sandwich panels, architectural concrete panels, ...). Seven different walls have been tested for this family.

2.1 Ageing types

All the samples were tested before and after ageing phases. Three types of ageing were implemented successively on the samples.

- Ageing representing wind effects and storms.
- Ageing representing the variation of moisture
- Ageing representing the variation of temperature

The succession of ageing are adapted to the influence of the ageing on the type of walls

The ageing representing the wind effect is implemented through storms. Each storm has

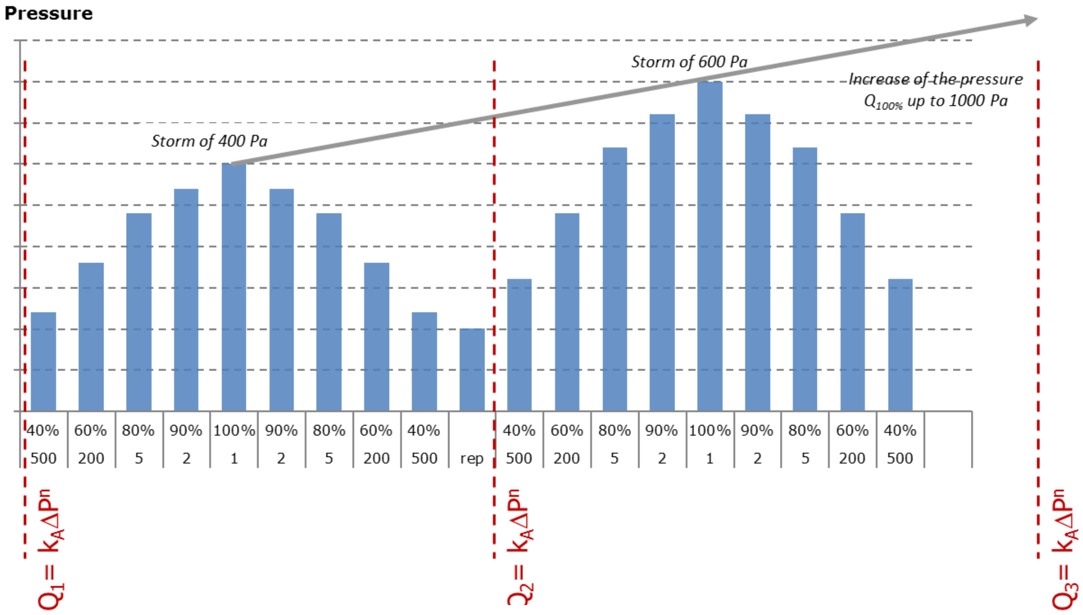


Figure 1: Ageing due to wind effect

1,415 wind cycles ranging from 40% to 100% of the maximum value of wind pressure (as described on figure 1). Four different storms were applied on the walls. After each storm, the air permeability has been measured.

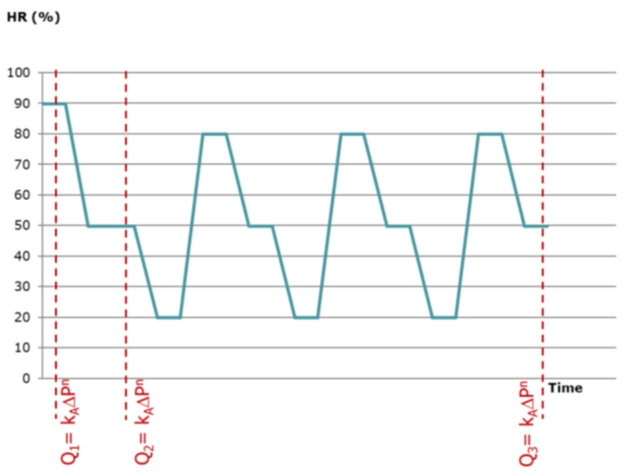
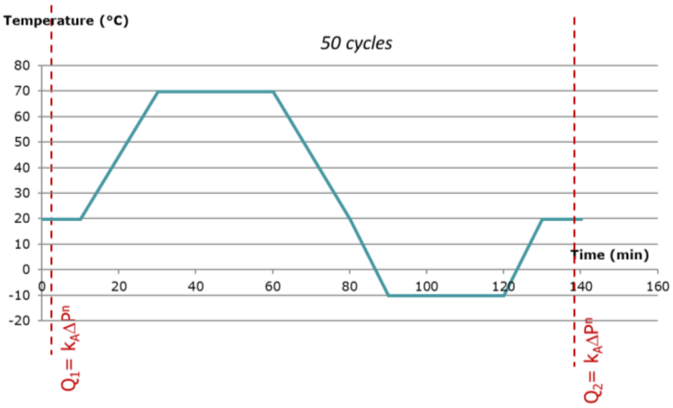


Figure 2: Ageing due to Moisture effect

The ageing representing the variation of moisture is implemented through rapid variation of the air moisture. After a first stabilisation up to 50% HR, three cycles from 20 to 80% are applied on the inside part of the walls (as described on figure 2). Each cycle lasts one day. It represents short-term variations therefrom that may occur in buildings with indoor climate control (for example in bathrooms, ...).



Ageing types due to temperature effect are applied to the outer side of the walls. 50 temperature cycles are performed (as described on figure 3). An airtightness tests is realized after at the end of the ageing procedure.

Figure 3: Ageing due to temperature effect

All the permeability tests are realized both in over- and underpressure. Based on these tests, it is possible to determine the following equations $Q_n = k_A \Delta P^n$ (as described on figure 4).

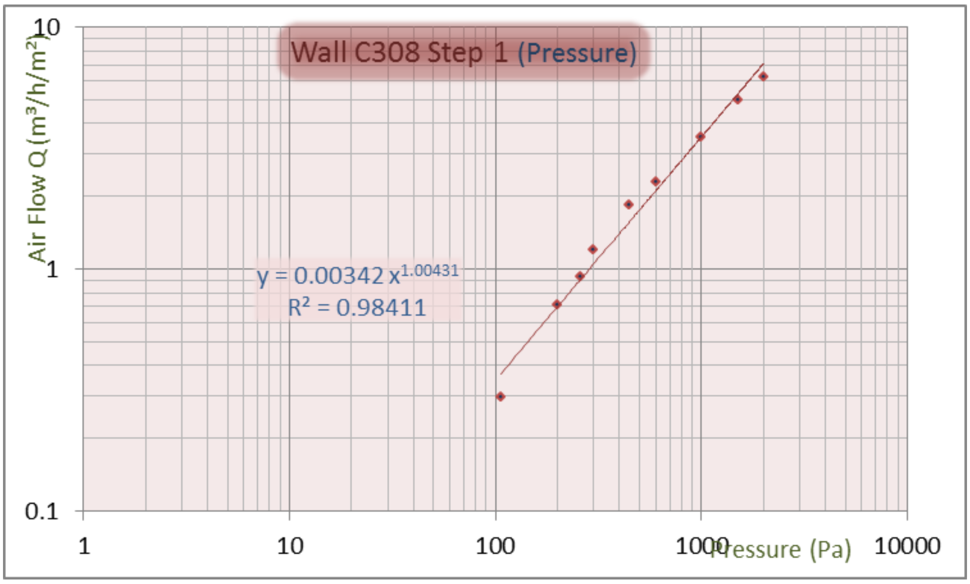


Figure 4: Graph (Q,ΔP) – Sampling (plastering)

46 walls were tested representing more than 700 graphs (Q,ΔP). All the ageing tests realized on a specific wall are summarized on one graph (Q_{50}, Ageing test) to represent the evolution of the airflow at 50Pa after each step of the ageing process. The figure 5shows an example of the evolution for walls whose airtightness is ensured by a wood panel with tape.

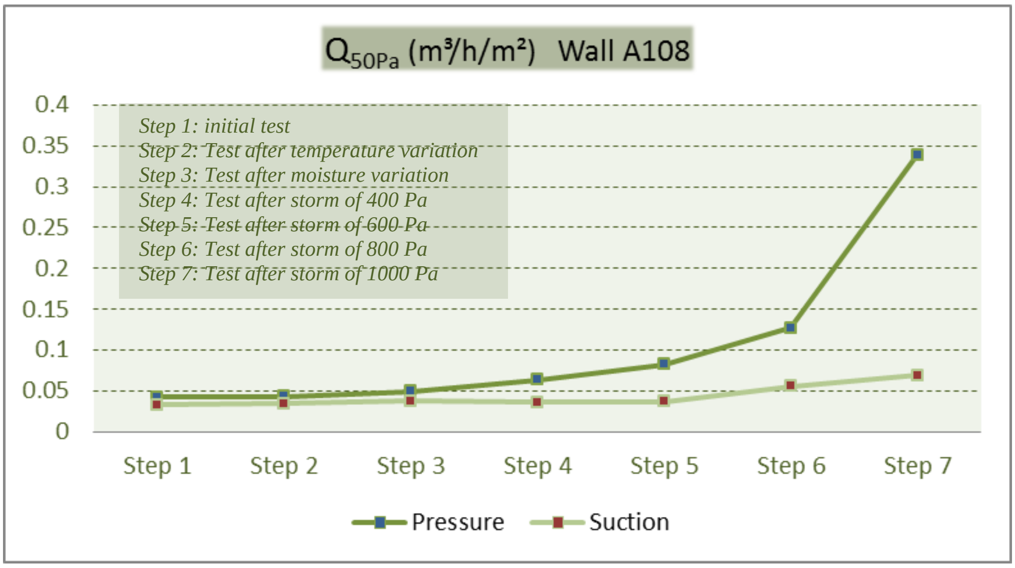


Figure 5: Evolution of the Q50Pa (case of OSB12mm panel with tape (type 3)and lathing)

The tested samples are representative of the existing building method in Belgium. The results of this research are not exhaustive and could not cover all the existing technics.
The samples were built carefully in laboratory conditions in order to start in optimal situation before proceeding with ageing. The purpose of this research is to confirm the durability of the performance of the investigated systems.

2.2 « Walls of blocks / bricks whose airtightness is ensured by coatings/plastering »

2.2.1 Walls of blocks / bricks whose airtightness is ensured by internal plastering

On those samples the ageing steps are established by a first application of moisture variation, temperature variations and finally storm cycles.
The interior coating systems achieve good airtightness performance, as well the initial performance as after ageing ($q50<0.1 m^3/h/m^2$). However we can note some learnings:

- Only moisture and thermal ageing influence the airtightness;
- The thickness of the plastering and the smoothness influence the initial performance;
- The storms ageing up to 1000 Pa haven't any influence on the performances;
- Thin plastering (thickness ≤ 6mm) shows a significant loss of airtightness after hygrothermal cycles. This loss is due to micro-cracks in the plastering. The effect of hygrothermal cycles in steps 2 (moisture variation) and 3 (thermal variation) of a 6 mm plaster (evolution shown in figure 6) are higher than the influence from wind effect ageing. Performance after ageing are still remaining acceptable;

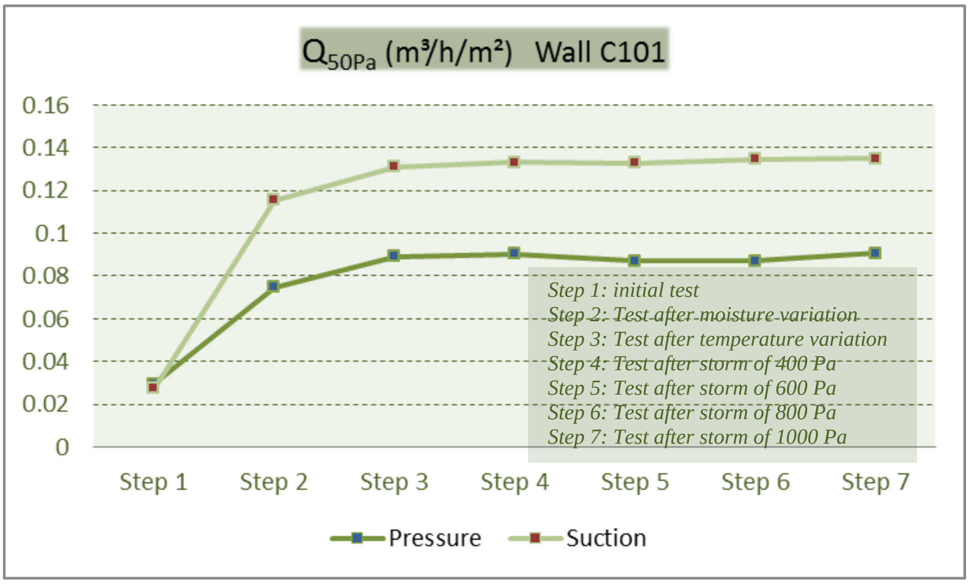


Figure 6: Evolution of the Q50Pa (case of 6mm plastering)

- It's also interesting to note the quality of the surface (finishing) influences the level of the initial performance but does not influence the risk of micro-cracking (this is even more pronounced in thin plastering). Some samples have required the application of new plastering to start with better initial performances;
- Applying a double plastering influences the initial airtightness performance. However the risk of degradation of the plastering is influenced by the thicknesses of the layers.

In the case of clay-based coatings, the airtightness is influenced by the thickness.

- The grain size fluctuations of the clay are compensated by the thickness of the applied clay (in the research : 28 and 51 mm); For the 28mm thick, the Q_{50Pa} stays around 0.1m³/h/m² all along the aging procedure. For the 51mm thick, the Q_{50Pa} stays between 0.012 and 0.02 m³/h/m² all along the aging procedure.
- For both thicknesses, with clay-based coatings, the storms cycles have no significant influence on the evolution of the performances. The action of hygrothermal ageing has less influence on the airtightness especially for the higher thickness. This could be explained because of the test procedure (the thermal and moisture variation are quite rapid – the clay did not have any time during humidity cycles to stabilize the humidity in the material). The initial airtightness performance of thicker clay-based coating was maintained. A consequent loss of airtightness could come into consideration for buildings where moisture conditions are not mastered quickly.

2.2.2 Walls of blocks / bricks whose airtightness is guaranteed by external coatings/plastering

The same ageing procedure was followed (see§2.2.1).The following outputs emerge:

- The influence of humidity cycles depends strongly on the used coating system (as well as the methods of implementation). For each product, an initial performance testing by the fabricant should be required;

- The overriding factors influencing the initial performance are:
  - The particle size of the products used
  - Pre-layers and preparation layers
  - The thickness of the layers
  - The nature of the binder
- The initial values (Q_{50Pa}) are varying between 0.004 up to 0.8 m³/h/m². After ageing procedure, the Q_{50Pa} is going up to 0.01 m³/h/m² for the best airtight one and up to 1.7m³/h/m² for the most degraded one.
- The action of pressure cycles is only marked from high pressures storms (over 800 Pa) but it should be noted that the influence of ageing is relatively limited on the coatings. These coatings have been developed to meet the external application and watertight requirements. So the number of cracks is rather limited with these products.

2.3 Walls whose airtightness is ensured by panels

The fixing of panels and techniques of airtightness (continuity between panels) can significantly influence the performance of the wall.

The ageing procedure is defined by a first application of temperature variations and moisture variations and finally ageing due to pressure.

We can note the following findings:

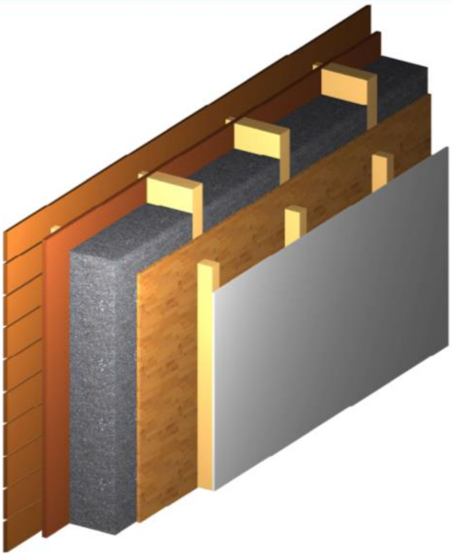


Figure 7: Sample with panel

When walls with joints between panels are glued, they delivers a performance for which ageing has limited influence. Note that the (PU based) glue in the grooves was carried out with particular care along the grooves to ensure the continuity of all the collages. The analysis does not include the variability of implementations. The effect of ageing is limited in time and humidity fluctuations were fast enough (cycles less than 24 hours). This glue must meet the criteria for structural bonding.

When sealing between panels is ensured by tape, it is essential to ensure the compatibility between the panels and the tape. Strengthen the tape by a lathing ensures the continuity of the airtightness. Indeed, tests have shown that the storms 800 and 1000 Pa generate significant impairments in tape (although this is limited for optimal combinations tape / panel). The effect of hygrothermal cycles (short period) remains low on these systems (in case of rapid management of internal conditions). However, tests realized by realizing longer hygrothermal cycles (no active control) generate higher damage. The following figure shows the evolution of airtightness for complete walls whose airtightness is ensured by panels (OSB3-15mm) and tapes between panels without lathing.

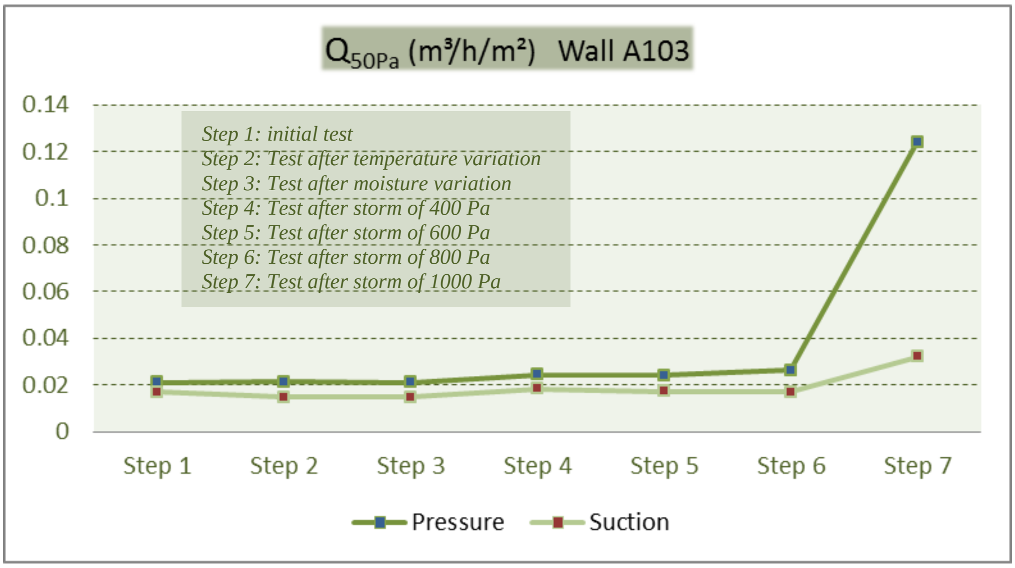


Figure 8: Evolution of the Q50Pa (case of panels with tape)

When a strapping protects these tapes, the degradation is significantly reduced. This construction method ensures the sustainable performances. It is also clear that in the case of tapes placed on non-reinforced seams (upper parts of frames), the tapes are strongly solicited and damages appear with high pressure storms (from 800Pa).

When tightness between panels is provided by sealants under lathing, the solution offers a sustainable solution. The following figure gives the evolution of the Q50 for panels whose continuity is ensured by a compressed sealant.

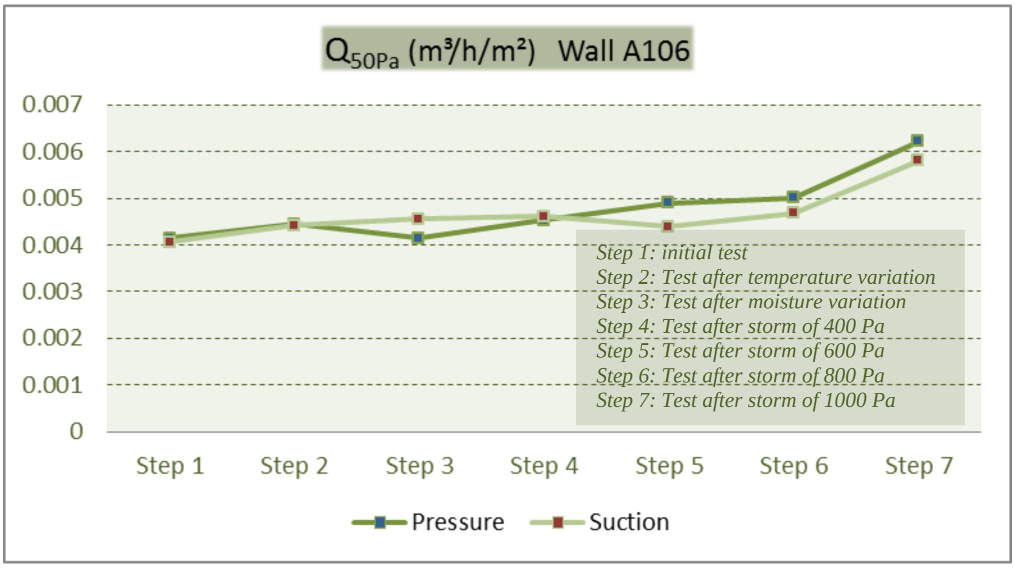


Figure 9: Evolution of the Q50Pa (case panel + compressed sealant)

2.4 Walls whose airtightness is guaranteed by a membrane

The ageing procedure is defined by a first application of temperature variations and moisture variations and finally ageing due to pressure.

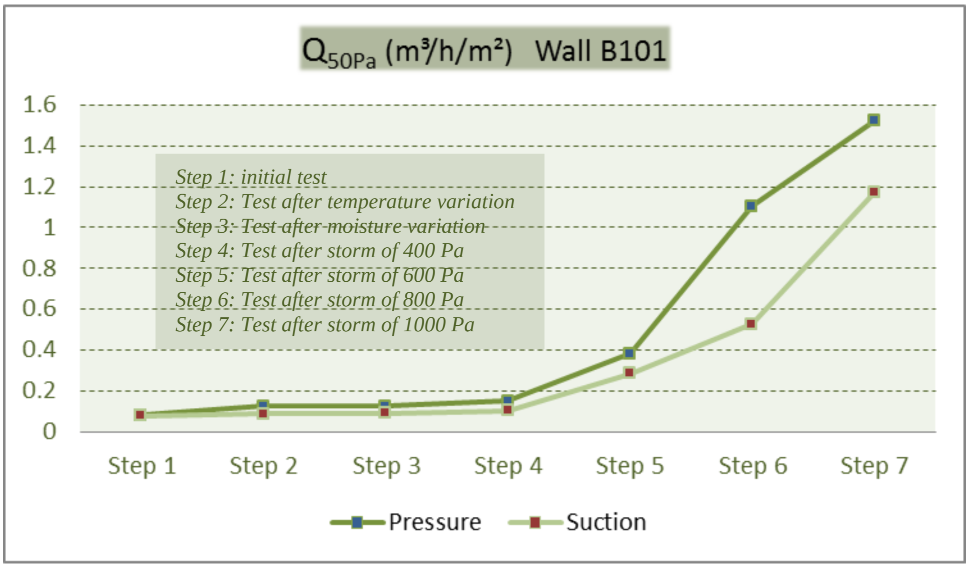


Figure 10: Evolution of the Q50Pa (case of stapling membrane)

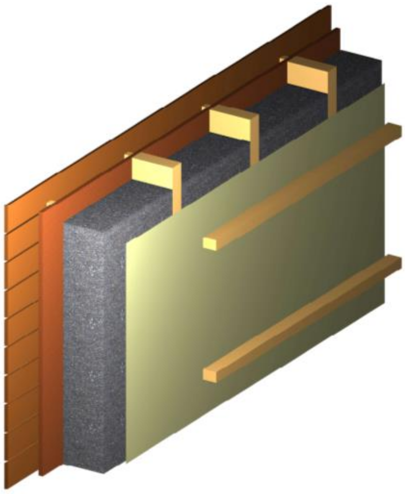


Figure 11: Sample with membrane 1

- Stapling the membrane is a risky method, the ageing effect has a consequent impact if the stitching is not supported by lathing or a compatible tape;
- Connections between membranes need to be done with tape single sided or double sided, or folded and lathing, or mastic bound. If construction is exposed to wind, it will be applied by the additional lathing recovery;
- The horizontal lathing (technique applied to hold the membrane during the insulation blowing) is not sufficient when the construction is exposed to wind;
- The compatibility between membrane and tape requires verification. Indeed, although the initial bonding seems appropriate, hygrothermal or mechanical (wind) ageing may degrade the airtightness of these collages;
- When the membranes are glued with a flexible stand, folding the two membranes with double-sided tape gives significant performance; However, if the building is exposed to the wind, the protection of such recovery is necessary.

2.5 Walls whose airtightness is ensured by industrialized systems (sandwich panels, architectural concrete panels, …).

The prefabricated sandwich panel construction requires improved joints between panels design. For these walls, the ageing procedure is a first application of pressure cycles, variations in temperature and finally humidity variations.

- When the links between sandwich panels is provided by a closed cell foam seal and a silicone, if the closed cell seal is compressed by fixing the panel, the continuous seal is ensured. The features of construction must allow the compression of the seal. Continuity at the corners remains difficult. The silicone gasket completes the seal. The ageing will not have any effect on the airtightness of this system
- If the sealing wall is provided by a closed cell foam seal, the gasket must be compressed with panels fixations therefore continuity is sealed. Continuity at the corners remains difficult. However, additional gasket or mastics must ensure the continuity of the seal. The compressed seals have not shown any degradation;

3 CONCLUSIONS

Several techniques can be identified in terms of airtightness sustainability. Some resist more at higher loads; it is then necessary to adapt the construction method according to the stresses. Thus, a construction particularly exposed to the wind requires additional lathing on membrane's connections. It is also important that the manufacturer communicates on the compatibility and performance of their product.

The results of this research will be used in future publications of the Belgian Building Research Institute.

4 ACKNOWLEDGEMENTS

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