Lessons learnt from the state of the art of airtightness durability: on-site measurements

Nolwenn Hurel[1*], Valérie Leprince[2]

1 PLEIAQ
2 Avenue de Mérande
73 000 Chambéry, France
**Corresponding author: nolwenn.hurel@pleiaq.net*

2 PLEIAQ
84 C Avenue de la Libération
69330 Meyzieu, France

FOREWORD

The content presented comes from the VIP (Ventilation Information Paper) "Durability of building airtightness" that will soon be published on the Airbase, the AIVC bibliographic database.

KEYWORDS

Airtightness, durability, on-site measurements, literature review

1 REVIEW OF ON-SITE STUDIES TESTING BUILDINGS AIRTIGHTNESS DURABILITY

A literature review of 14 field measurements studies from 8 countries is presented, with various numbers and type of buildings which had their air permeability measured both after completion and years later. One can draw the following conclusions from the results:

- **Airtightness is not robust:** Significant changes in air permeability with time are observed for at least part of the tested houses in all studies except one.
- **Airtightness tends to deteriorate after completion:** The mean change in air permeability is positive for all studies. The average of all mean changes weighted by the sample size gives an increase of 24%.
- **Changes in airtightness are very variable:** For each study results differ considerably between the tested houses, with almost always at least one presenting an improved airtightness (by up to 40%) and almost always at least one presenting a very deteriorated airtightness (by up to 580%).
- **Changes in airtightness occur quickly after construction:** the mean change in measured air permeability does not seem to clearly increase with the building age, which would mean that changes occur mostly within the first (1 or 2) year(s) of the building use.
- **Changes in airtightness in percentage does not seem to be correlated to the initial air permeability level.** This however means that changes in absolute terms are bigger for initially more permeable buildings.
- **Changes in airtightness does not seem to strongly depend on the main construction material:** both wooden and concrete constructions were sometimes found to have a durable airtightness and other times a strongly deteriorated airtightness.

2 KEY FACTORS FOR AIRTIGHTNESS CHANGE OVER TIME

Based on the results of field studies regarding the evolution of the air permeability in real buildings, it seems that the air permeability, when it increases, increases in the first years and

then stabilises. Different factors have been identified in the literature to explain the increase of air permeability, sometimes contradicting each other:

- **Building's natural "movements"** with in particular the first house heating that may induce the shrinkage of mastics and/or structural timber (Wingfield et al., 2008); shrinkage of mastic when a backer rod is not used (Feist et al., 2016; Wingfield et al., 2008); and structure movements and packing may induce cracking in the junctions between the air barrier and penetrations (Chan et al., 2015).
- **External interventions:** Drilling hole into the envelope deteriorating the air barrier system (ADEME, 2016) (Novák, 2018); installation of cables or ductwork after the completion of the building (Verbeke and Audenaert, 2020).
- **Specific building materials and construction types**:
    - Uncertain impact of the number of storeys: In (Moujalled et al., 2021) 2-storey houses seem to deteriorate more than 1-storey ones, but this probably not a predominant factor as according to (Philips et al., 2011) houses generally became leakier than the flats
    - Air barrier made by plasterboard seems to deteriorate more in average than air barrier made with membrane (Proskiw, 1998) (Johnston and Lowe, 2006) (ADEME, 2016)
    - Air barrier made with membrane can however also potentially strongly deteriorate: timber frame dwellings showed the largest change in airtightness compared to plastered masonry in (Philips et al., 2011). Especially in case of exposed wood frame roofs; which seems to deteriorate more than other roofs according to (Moujalled et al., 2021).
- **Poor workmanship**
- **Unsuitable implementation conditions** for adhesives and mastic such as cold and/or dusty conditions (Antonsson, 2015).

It is interesting to notice that, in many studies, the airtightness of some of the tested dwellings had improved. Apart from measurement uncertainty, it could be due to the settlement (Philips et al., 2011); the user reducing the air inlets to decrease the heating load (Ramos et al., 2013); or wood expansion with humidity (Moujalled et al., 2021).

3 RECOMMENDATIONS FOR FUTURE FIELD STUDIES

Unfortunately, very few studies have tried to isolate one specific factor to investigate its impact on durability. In order to go beyond these factors, field studies shall include in the future the following:

- Ideally, repeated measurements year after year (and even every few months for the first 2-3 years) on large sample sizes
- Questionnaires to occupants to identify drillings made in the air barrier after the first test and check with leakage detection consequences of drilling and to check if air inlets have been reduced (for heating load reduction purpose as observed by Ramos et al. (Ramos et al., 2013)).
- Information about construction details, products used for the air barrier (compatibility of products, whether or not backer rod is used under mastics), the period when the air-barrier was laid out (during the heating period or not), and whether the air-barrier has been heated prior to the first test.

Moreover, the following recommendations would help to reduce test result variability due to the testing procedure:

- The same standardized procedure should be followed for each test (for example ISO 9972), including for the calibration of measurement devices.

- A qualified tester shall perform tests; if possible the same for all tests.
- The measurement and data analysis methodology should be documented in details so that repeated measurements can be performed as closely as prior tests, including a precise description of the building preparation (locked/unlocked external doors, etc).
- Measurements shall be performed in low wind conditions.
- Airtightness level shall rather be compared at 50 Pa than 4 or 10 Pa.
- The average of pressurisation and depressurisation shall be used for comparison.
- For wood houses, tests shall be performed in the same season.

4 ACKNOWLEDGEMENTS

The authors would like to thank ADEME and INIVE for funding this literature review.
The views and opinions of the authors do not necessarily reflect those of ADEME or INIVE. The published material is distributed without warranty of any kind, either expressed or implied. The responsibility for the interpretation and use of the material lies with the reader. The authors should in no way be held responsible for damages resulting from its use. Any liability arising from the use of this report is the responsibility of the user.

5 REFERENCES

ADEME, 2016. QUELLE PÉRENNITÉ DE LA PERMÉABILITÉ À L ' AIR des maisons individuelles BBC en Normandie ?

Antonsson, U., 2015. Utveckling av metodik för verifiering av beständighet hos system för lufttäthet, etapp 1.

Chan, W.R., Walker, I.S., Sherman, M.H., 2015. Durable Airtightness in Single-Family Dwellings-Field Measurementsand Analysis. International Journal of Ventilation 14, 27–38.

Feist, W., Ebel, W., Peper, S., Hasper, W., Pfluger, R., Kirchmair, M., 2016. 25 Jahre Passivhaus Darmstadt Kranichstein. Darmstadt.

Moujalled, B., Leprince, V., Berthault, S., Litvak, A., Hurel, N., 2021. Mid-term and long-term changes in building airtightness: A field study on low-energy houses. Energy and Buildings 250, 111257. https://doi.org/10.1016/j.enbuild.2021.111257

Novák, J., 2018. Assessment of durability of airtightness by means of repeated testing of 4 passive houses. Presented at the 39th AIVC Conference "Smart Ventilation for Buildings," Antibes Juan-Les-Pins, France.

Philips, T., Rogers, P., Smith, N., 2011. Ageing and airtightness How dwelling air permeability changes over time. Milto Keynes.

Ramos, N., de Freitas, V.P., Pereira, P.F., Curado, A., Machado, A., 2013. Application of blower door measurements IN the evaluation of workmanship influence in airtightness, in: Proceedings of the 34th AIVC - 3rd TightVent - 2nd Cool Roofs' - 1st Venticool Conference. Athens, Greece.

Verbeke, S., Audenaert, A., 2020. A prospective Study on the Evolution of Airtightness in 41 low energy Dwellings. E3S Web Conf. 172, 05005. https://doi.org/10.1051/e3sconf/202017205005

Wingfield, J., Bell, M., Miles-Shenton, D., South, T., Lowe, B., 2008. Evaluating the Impact of an Enhanced Energy Performance Standard on Load-Bearing Masonry Domestic Construction. Leed.