Assessment of long-term and mid-term building airtightness durability: field study of 61 French low energy single-family dwellings

Bassam Moujalled*, Sylvain Berthault, Andrés Litvak, Valérie Leprince, and Gilles Frances

*bassam.moujalled@cerema.fr

Introduction

- The French research project DURABILITAIR (2016-2019)
  ✓ to improve our knowledge on the variation of buildings airtightness through onsite measurement campaigns (Task 2) and accelerated ageing in laboratory controlled conditions (Task 3)

- Literature review (task 1) showed an important evolution over time of the air permeability in real buildings, especially in the first 3 years

- The second task of the project deals with the quantification and qualification of the durability of building airtightness of single detached houses through field measurement at:
  ✓ mid-term scale (MT)
  ✓ long-term scale (LT)
Methodology

- MT and LT measurement campaigns based on two samples of single-detached low-energy dwellings:
  - All dwellings measured upon completion and treatment of airtightness well known
- MT measurement campaign (1-3 years):
  - Sample of 30 new single-detached dwellings
  - The airtightness of each dwelling was measured once per year over the 3-year period [measurements n1, n2 & n3]
  - Five dwellings were measured twice per year (impact of seasonal variations)
  - For six dwellings, the airtightness of an installed window was measured once per year over the 3-year period
- LT measurement campaign (5-10 years):
  - Sample of 31 single-detached dwellings constructed during the last 10 years
  - The airtightness of each dwelling was measured once [measurement nx]
- Measurement protocol based on ISO 9972 and its French implementation guide, with additional requirements:
  - Measurements to be performed under the same conditions as the measurement upon completion n0 both in pressurization and depressurization
  - Detailed qualitative leakage detection to be performed
  - Questionnaires for occupants to be filled at each measurement regarding the action of the occupants on building envelope
RESULTS

Characteristics of buildings

Year of construction

<table>
<thead>
<tr>
<th>Year of construction</th>
<th>Nb. of dwellings</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>0</td>
</tr>
<tr>
<td>2010</td>
<td>0</td>
</tr>
<tr>
<td>2011</td>
<td>0</td>
</tr>
<tr>
<td>2012</td>
<td>5</td>
</tr>
<tr>
<td>2013</td>
<td>10</td>
</tr>
<tr>
<td>2014</td>
<td>15</td>
</tr>
<tr>
<td>2015</td>
<td>20</td>
</tr>
<tr>
<td>2016</td>
<td>25</td>
</tr>
</tbody>
</table>

Average timespan between measurements

MT sample:
- n0-n1 : 1.7 yr (from 1.1 to 2.7)
- n1-n2 : 0.7 yr (from 0.4 to 1.2)
- n2-n3 : 0.9 yr (from 0.4 to 1.7)
- n0-n3 : 3.4 yr (from 2.8 to 4.2)

LT sample:
- n0-nx : 4.6 yr (from 2.6 to 8)
### Characteristics of buildings

**Type of material & air barrier**

<table>
<thead>
<tr>
<th>Material &amp; Air Barrier</th>
<th>Mid-Term</th>
<th>Long-Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Brick</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Wood</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Concrete</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Brick</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Wood</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

**MT sample:**
Masonry walls with interior insulation:
Airtightness by plasterboards and mastics at the inside facing of the walls (C)

**LT sample:**
Masonry walls with interior insulation: Airtightness by coating on the masonry (B) or by plasterboards and mastics at the inside facing of the walls (C)
Wood frame houses with insulation between studs: Airtightness by the vapour barrier (A)

### Evolution in $q_{50}$

**MT sample**

**Evolution of mean $q_{50}$:**

- **n0-n1:** $+58.9 \text{ m}^3/\text{h}$ / $+18\%$
  
  *(p-value = 0.037)*
  
  *Timespan = 1.7 years*

- **n0-n2:** $+57.2 \text{ m}^3/\text{h}$ / $+18\%$
  
  *(p-value = 0.026)*
  
  *Timespan = 2.7 years*

- **n0-n3:** $+60.4 \text{ m}^3/\text{h}$ / $+19\%$
  
  *(p-value = 0.037)*
  
  *Timespan = 3.4 years*
**Evolution in $q_{50}$**

**LT sample**

Evolution of mean $q_{50}$:

$\text{n}_0 - \text{n}_x: +67.7 \text{ m}^3 \text{h}^{-1} / +20\%$

($p$-value $= 0.002$)

Timespan = 4.6 years

**Evolution in $q_{50}$ vs. Timespan**

**MT & LT samples**

No correlation between the evolution in $q_{50}$ and the age of the houses for both MT and LT samples
Analysis of explanatory factors

MT sample

Δ$q_{50}<$50 m³.h⁻¹
5 houses

-50 $<$ Δ$q_{50}$$<$+50
13 houses

+50 $<$ Δ$q_{50}$$<$150
6 houses

Δ$q_{50}$$>$+150 m³.h⁻¹
5 houses

### Analysis of explanatory factors

**Nb. Of levels (MT)**

2-storey houses seem to deteriorate more than 1-storey houses → Structural movement?

1-storey (20)
2-storey (10)

Δ$q_{50}<$50 m³.h⁻¹
5 houses

-50 $<$ Δ$q_{50}$$<$+50
13 houses

+50 $<$ Δ$q_{50}$$<$150
6 houses

Δ$q_{50}$$>$+150 m³.h⁻¹
5 houses
Analysis of explanatory factors

Type of roof (MT)

- Light frame (20)
- Traditional wood frame (8)
- Exposed Traditional wood frame (2)

2 exposed wood frame houses with same type of air barrier: +20% vs +180%

→ conditions of implementation?

Analysis of explanatory factors

Type of material (LT)

Wood houses tend to stabilise or even improve over years
→ expansion of wood with humidity?
Evolution of leakages

**MT sample: n3-n0**

Increase of leakages C, F, D & G

**NO CORRELATION** with the evolution in $q_{50}$

<table>
<thead>
<tr>
<th>Increase of leakages C, F, D &amp; G</th>
<th>NO CORRELATION with the evolution in $q_{50}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>B: junctions wall/slab</td>
<td></td>
</tr>
<tr>
<td>C: doors and windows</td>
<td></td>
</tr>
<tr>
<td>D: penetration through envelope</td>
<td></td>
</tr>
<tr>
<td>E: trapdoor</td>
<td></td>
</tr>
<tr>
<td>F: electrical components</td>
<td></td>
</tr>
<tr>
<td>G: junctions wall/window</td>
<td></td>
</tr>
<tr>
<td>H: other leakages</td>
<td></td>
</tr>
</tbody>
</table>

**CONCLUSIONS**
Conclusions

▪ Same evolution of airtightness at mid and long term
  ✓ Similar increase in $q_{50}$ at mid and long-term (+18% and +20% respectively)
  ✓ No correlation with the age of construction
  ✓ Deterioration mainly during the first 2 years and then stabilisation

▪ Significant increase in the number of leakages for:
  ✓ Doors and windows, electrical components, penetrations through envelope & junctions between walls and windows
  ✓ But no correlation with the variation in $q_{50}$

Conclusions

▪ Explanatory factors of the evolution of the airtightness:
  ✓ No impact for constructor, type of air-barrier, type of floor, type of heating, specific HVAC equipment
  ✓ No impact for seasonal variation
  ✓ The airtightness of wood houses tend to stabilise or even improve over years
  ✓ 2-storey houses seems to deteriorate more than 1-storey ones
  ✓ Studied factors unable to explain the variations:
    ✓ Other factors, such as conditions of implementation of the air-barrier, need to be explored
Thanks...

Projet DURABILIT’AIR
https://www.durabilitair.com/

AIVC Webinar – Durability of building airtightness: Assessment through field measurements | 30 January 2020