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 [measurement n0] 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 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

Average timespan between measurements

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

**LT sample:**
- \( n0-nx : 4.6 \text{ yr (from 2.6 to 8)} \)
### Characteristics of buildings

**Type of material & air barrier**

<table>
<thead>
<tr>
<th>Material</th>
<th>Air barrier-A</th>
<th>Air barrier-B</th>
<th>Air barrier-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>4</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Brick</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Wood</td>
<td>1</td>
<td>1</td>
<td>1</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 $q_{50}$:**

- $n_0-n_1$: +58.9 m$^3$.h$^{-1}$/ +18%
  - $(p$-value = 0.037)
  - Timespan = 1.7 years

- $n_0-n_2$: +57.2 m$^3$.h$^{-1}$/ +18%
  - $(p$-value = 0.026)
  - Timespan = 2.7 years

- $n_0-n_3$: +60.4 m$^3$.h$^{-1}$/ +19%
  - $(p$-value = 0.037)
  - Timespan = 3.4 years
Evolution in $q_{50}$

**LT sample**

Evolution of mean $q_{50}$:

$n_0-n_x$: $+67.7 \, m^3\cdot h^{-1}/ +20\%$  
($p$-value $= 0.002$)  
Timespan = 4.6 years

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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

Δq_{50} < -50 m³·h⁻¹
5 houses

-50 < Δq_{50} < 50
13 houses

+50 < Δq_{50} < 150
6 houses

Δq_{50} > +150 m³·h⁻¹
5 houses

Analysis of explanatory factors

Nb. Of levels (MT)

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

1-storey (20)
2-storey (10)
Analysis of explanatory factors

**Type of roof (MT)**

<table>
<thead>
<tr>
<th>MT sample</th>
<th>Δq_{50} &lt; 50 m³·h⁻¹</th>
<th>Δq_{50} &gt; 50 m³·h⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>LT sample</td>
<td>-50 &lt; Δq_{50} &lt; 50</td>
<td>+50 &lt; Δq_{50} &gt; 150</td>
</tr>
<tr>
<td>5 houses</td>
<td>13 houses</td>
<td>6 houses</td>
</tr>
</tbody>
</table>

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

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

**Type of material (LT)**

<table>
<thead>
<tr>
<th>LT sample</th>
<th>Δq_{50} &lt; 50 m³·h⁻¹</th>
<th>Δq_{50} &gt; 150 m³·h⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood frame (6)</td>
<td>5 houses</td>
<td>6 houses</td>
</tr>
<tr>
<td>Hollow bricks (21)</td>
<td>8 houses</td>
<td>11 houses</td>
</tr>
<tr>
<td>Concrete blocks (3)</td>
<td>13 houses</td>
<td>5 houses</td>
</tr>
</tbody>
</table>

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

- Wood frame (6)
- Hollow bricks (21)
- Concrete blocks (3)
Evolution of leakages
MT sample: n3-n0

Increase of leakages C, F, D & G
NO CORRELATION with the evolution in $q_{50}$

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/

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