Field measurement of the durability of building airtightness- review and analysis of existing studies

Valérie Leprince – INIVE

Tightvent Webinar 2020

Durabilit'air project

- 1st task of the Durabilit'air project

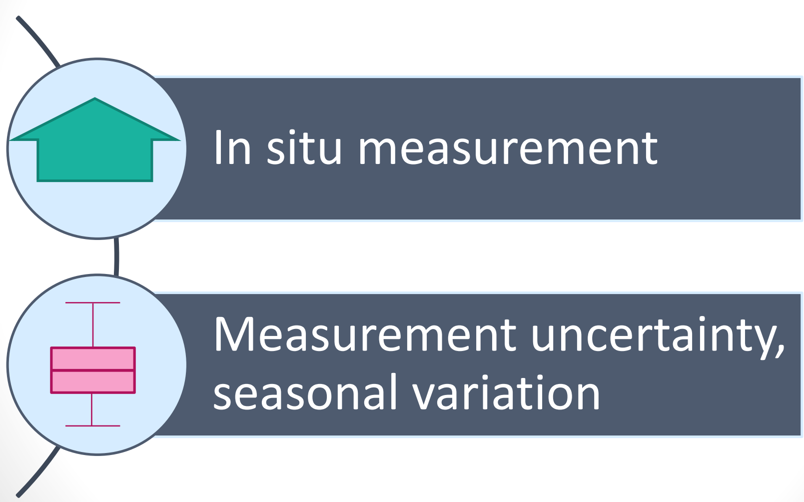
Founded by:

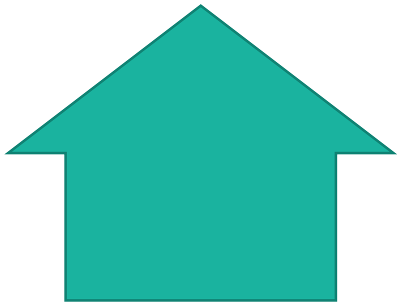
- Objectives of the project:
  - State of the art of major international research findings
  - Characterizing the evolution over time in mid and long term scales by on-site measurement campaigns
  - Developing a laboratory controlled method in order to test the accelerated ageing of airtightness systems;
  - Disseminating the main results of this work to promote best practices.

Objective of the state of the art

- Learn from previous studies
- Improve the protocol for the other tasks of the project
  - Field measurements
  - Laboratory testing

Durability tested on site





IN SITU MEASUREMENTS

USA	USA	Belgium	Sweden	Canada	France	Germany	UK
17	17	15	6	17	30	2	23
2001	2007	2010	1990	1985	2009	1990	2007
10-13 yr	5-7 yr	1-2 yr	10-20 yr	3 and 11 yr	5-6 yr	25 yr	1-3 yr
6 ACH	10 ACH	0,6 ACH	0,6 ACH to 4 ACH	1,5 ACH	0,8 ACH	0,6 ACH	4 ACH
+15%	0%	+36%	+162%	+6% (3yr) / +11% (11yr)	+50%	0% / 34 %	+25%
-25 / +140	-40 / +150	-3 / +120	-11 / +580	-16 / +60	- / -		-33 / +154
Chan & Sherman, 2014	Chan & Sherman, 2014	Bracke, Laverge, et al. 2016	Hansen & Ylmén, 2012	Prowski, 1998	ADEME, 2016	Feist, Ebel, et al., 2016	Philips, Rogers, et al., 2011

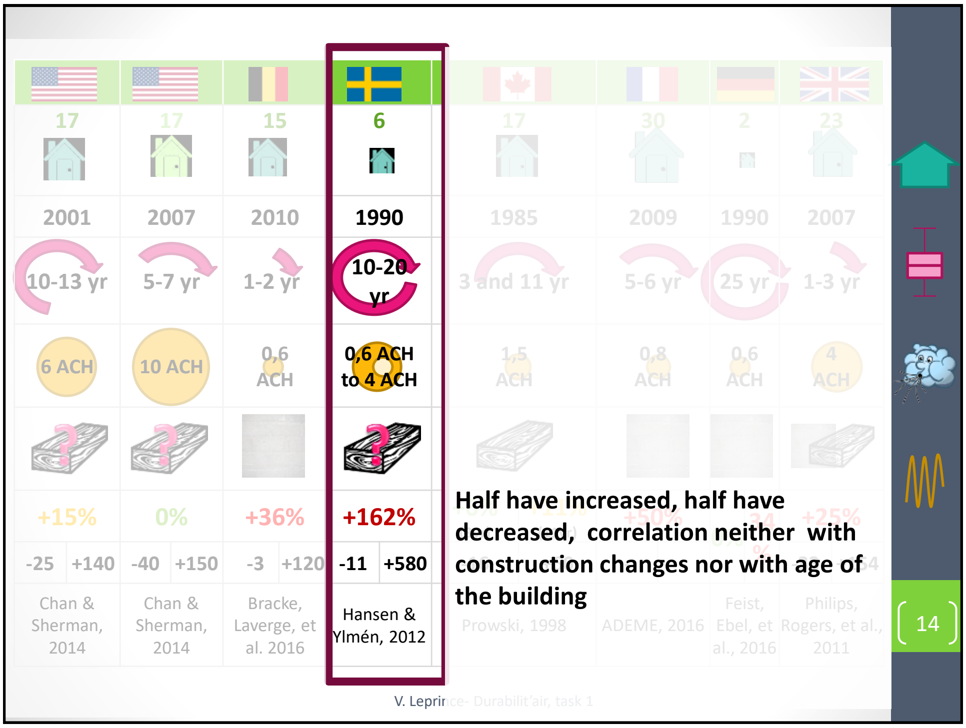
Country	USA	USA	Belgium	Sweden	Canada	France	Germany	UK
Number	17	17	15	6	17	30	2	23
Year	2001	2007	2010	1990	1985	2009	1990	2007
Period	10-13 yr	5-7 yr	1-2 yr	10-20 yr	3 and 11 yr	5-6 yr	25 yr	1-3 yr
Airtightness	6 ACH	10 ACH	0,6 ACH	0,6 ACH to 4 ACH	1,5 ACH	0,8 ACH	0,6 ACH	4 ACH
Variation	+15%	0%	+36%	+162%	[illegible] (3yr) (11yr)	+50%	0% 34 %	+25%
Range	-25 +140	-40 +150	-3 +120	-11 +580	-16 +60	- -		-33 +154
Reference	Chan & Sherman, 2014	Chan & Sherman, 2014	Bracke, Laverge, et al. 2016	Hansen & Ylmén, 2012	Prowski, 1998	ADEME, 2016	Feist, Ebel, et al., 2016	Philips, Rogers, et al., 2011

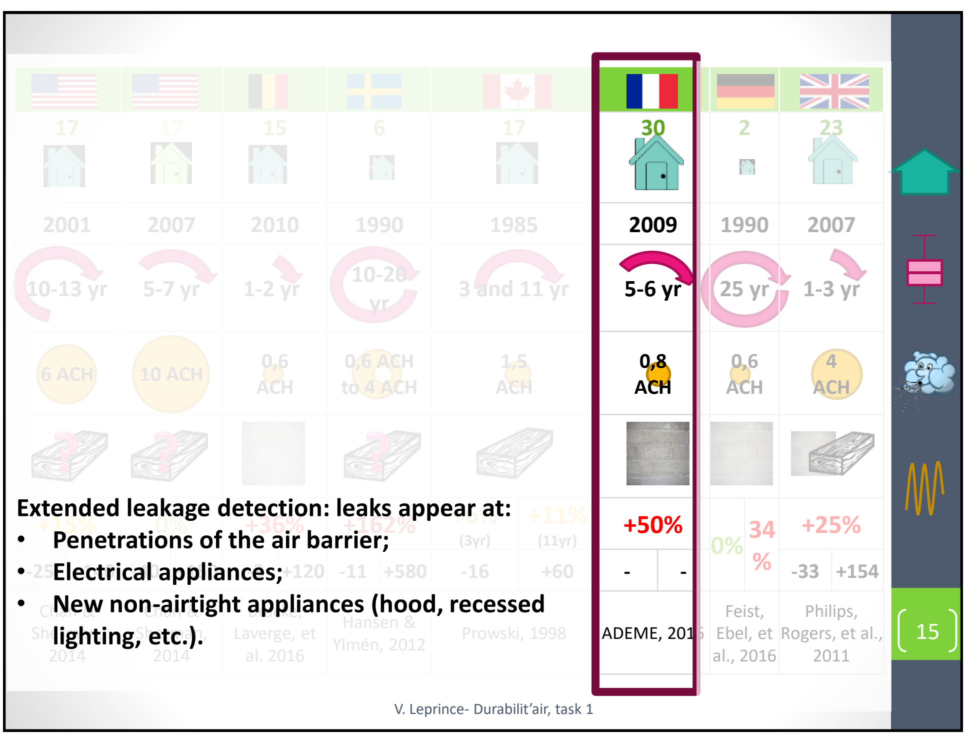
Difference due to structure movements in new buildings?

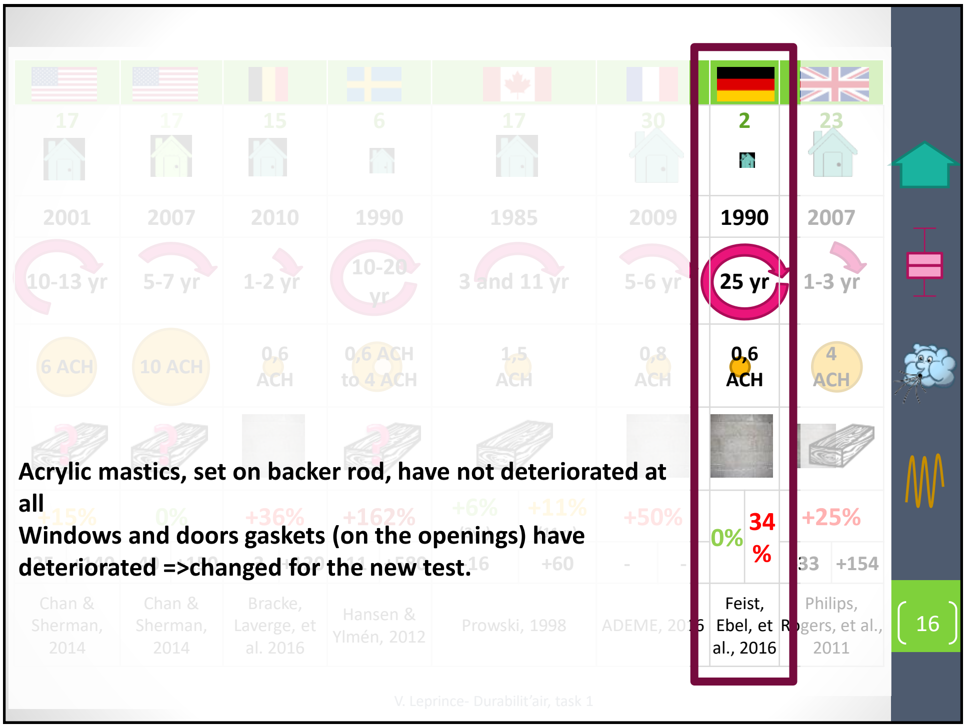
Country	USA	USA	Belgium	Sweden	Canada	France	Germany	UK
Number	17	17	15	6	17	30	2	23
Year	2001	2007	2010	1990	1985	2009	1990	2007
Period	10-13 yr	5-7 yr	1-2 yr	10-20 yr	3 and 11 yr	5-6 yr	25 yr	1-3 yr
Airtightness	6 ACH	10 ACH	0,6 ACH	0,6 ACH to 4 ACH	1,5 ACH	0,8 ACH	0,6 ACH	4 ACH
Variation	+15%	0%	+36%	+162%	[illegible]	+50%	34 %	+25%
Range	-25 +140	-40 +150	-3 +120	-11 +580	-16 +60	- -		-33 +154
Reference	Chan & Sherman, 2014	Chan & Sherman, 2014	Bracke, Laverge, et al. 2016	Hansen & Ylmén, 2012	Prowski, 1998	ADEME, 2016	Feist, Ebel, et al., 2016	Philips, Rogers, et al., 2011

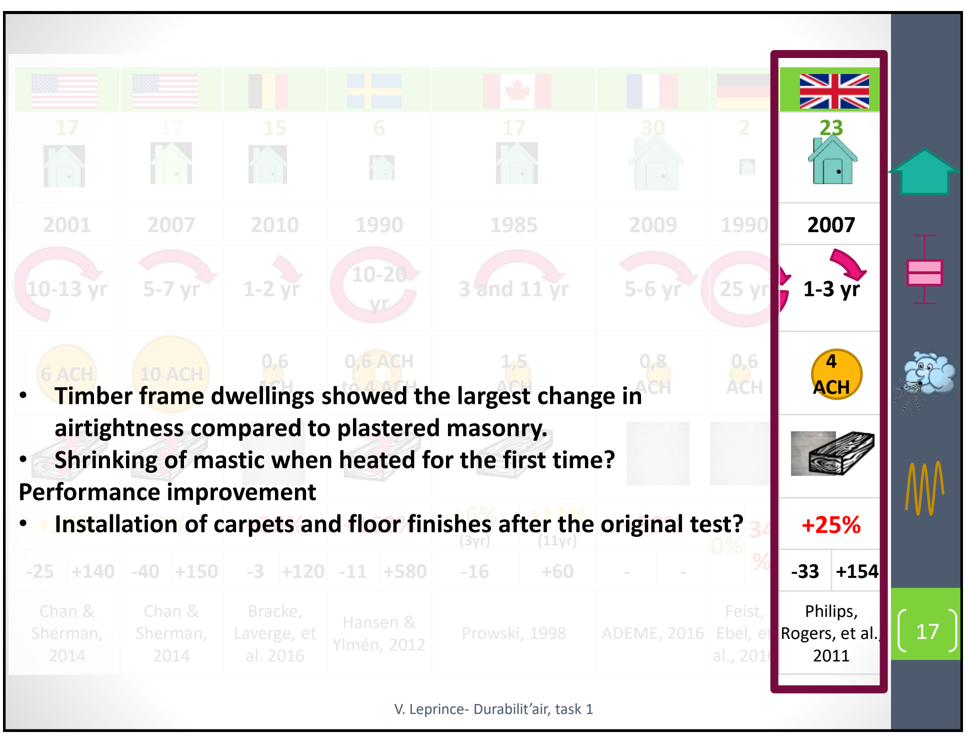
Building virtually identical (same craftsmen, same materials) => difference due to occupants behaviour?

Very low flowrate difference, measurement uncertainty?


6
1990
10-20 yr
0,6 ACH to 4 ACH
+162%
-11
+580
Hansen & Ylmén, 2012
2001
2007
2010
1985
2009
2007
10-13 yr
5-7 yr
1-2 yr
3 and 11 yr
5-6 yr
25 yr
1-3 yr
6 ACH
10 ACH
+15%
0%
+36%
-25
+140
-40
+150
-3
+120
Chan & Sherman, 2014
Chan & Sherman, 2014
Bracke, Laverge, et al. 2016
Half have increased, half have decreased, correlation neither with construction changes nor with age of the building
14
V. Leprince- Durabilit'air, task 1


30
2009
5-6 yr
0,8 ACH
+50%
-
-
ADEME, 2016
2
1990
25 yr
0,6 ACH
34 %
Feist, Ebel, et al., 2016
23
2007
1-3 yr
4 ACH
+25%
-33
+154
Philips, Rogers, et al., 2011
Extended leakage detection: leaks appear at:
• Penetrations of the air barrier;
• Electrical appliances;
• New non-airtight appliances (hood, recessed lighting, etc.).
15
V. Leprince- Durabilit'air, task 1


2
1990
25 yr
0,6
ACH
0%
34
%
Feist, Ebel, et al., 2016
Acrylic mastics, set on backer rod, have not deteriorated at all
Windows and doors gaskets (on the openings) have deteriorated =>changed for the new test.
16

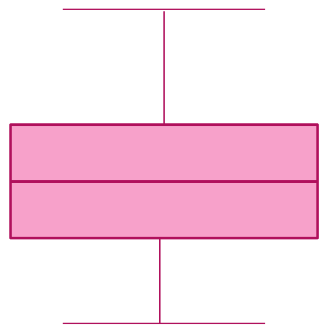

23
2007
1-3 yr
4
ACH
+25%
-33
+154
Philips, Rogers, et al. 2011
• Timber frame dwellings showed the largest change in airtightness compared to plastered masonry.
• Shrinking of mastic when heated for the first time?
Performance improvement
• Installation of carpets and floor finishes after the original test?
V. Leprince- Durabilit'air, task 1
17

Conclusion on-site ageing

- Seems that the airtightness decreases in the first years after completion and then stabilises.
- Explanation factors:
  - Heating houses for the first time may induce the shrink of mastics
  - Mastic shrinking when backer rod are not used
  - Structure movements and packing may induce cracking in the junctions between air barrier and penetrations
  - Occupants behaviour: Envelope drilling (lot in the first years), etc.
  - Unsuitable implementation conditions for adhesives and mastic (cold and/or dusty conditions).

Impact on the testing protocol

- Questionnaires to occupants to find out drillings made in the air barrier.
- Leakage detection and visual inspection at visible assemblies of air barrier with specific care on:
  - mastics,
  - penetrations of building structure inside the air barrier (ex. carpentry).
- Information about:
  - Products used for the air barrier (use of backer road, compatibility of products)
  - Construction details
  - Period when the air-barrier was layed-out (heating period or not)?
  - Air-barrier heated prior to the first test?



MEASUREMENT UNCERTAINTY AND SEASONAL VARIATIONS

Measurement uncertainty: reference pressure of indicator

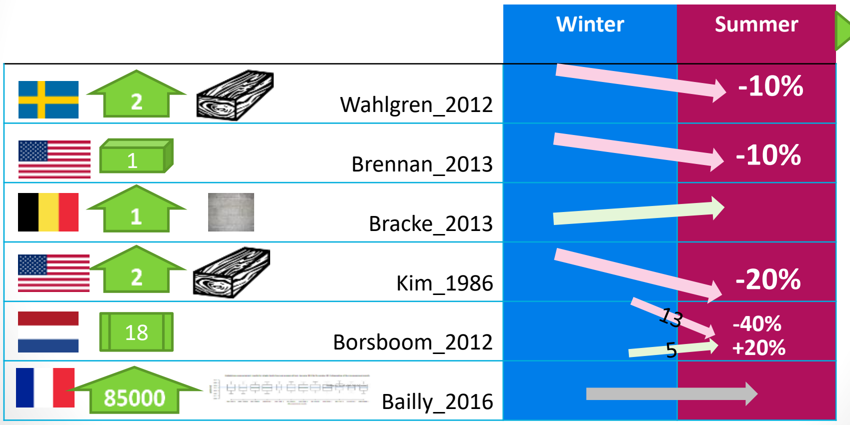
	4 Pa	50 Pa
Repeatability	3.5%	1.4%
Reproducibility	5.9%	2.4%
Wind impact(10m/s)	Max 60%	Max 12%

Sources: Delmotte_2011, Carrié_2014, Bracke_2014

Measurement uncertainty: seasonal variation

- Impact of **indoor humidity?**

$$\frac{Q_{50}}{\overline{Q_{50}}} = 0.991 \cdot \left(\frac{W_i}{\overline{W_i}}\right)^{0.11}$$



Impact on the testing protocol

- Reduce measurement uncertainty
  - Same qualified tester perform tests;
  - Reports precisely describe building preparation including locked and unlocked external doors.
  - Measurement devices calibrated according ISO 9972.
  - Measurements in low wind conditions.
  - Airtightness compared at 50Pa rather than 4 or 10 Pa.
    - In flowrate at 50 Pa rather than ratio (n50 or q50) take into account uncertainty
  - Average of pressurisation and depressurisation test
  - Better to perform test at the same season.

Conclusions

Airtightness changes through years

- Seems to decrease in the first years and then stabilise
- On site analysis required to explain measurement results

Low uncertainty required for interpretation

- 50 Pa indicator more reliable
- Test at same season if feasible

Thank you for your attention!

Questions?

Source: AIVC 2017 –Nottingham:
Publication available on Airbase

https://www.aivc.org/resource/durability-building-airtightness-review-and-analysis-existing-studies

FACULTY OF ENGINEERING AND ARCHITECTURE

DEPARTMENT OF ARCHITECTURE & URBAN PLANNING
BUILDING PHYSICS RESEARCH GROUP

DURABILITY AND MEASUREMENT UNCERTAINTY OF AIRTIGHTNESS IN EXTREMELY AIRTIGHT DWELLINGS

Wolf Bracke, Jelle Laverge, Nathan Van Den Bossche, Arnold Janssens

presenter: Wolf Bracke / 30 January 2020

GHENT UNIVERSITY

1

OUTLINE

- **Introduction**
- Test repeatability and seasonal variations
- Durability of airtightness
- Conclusions

GHENT UNIVERSITY

2

2

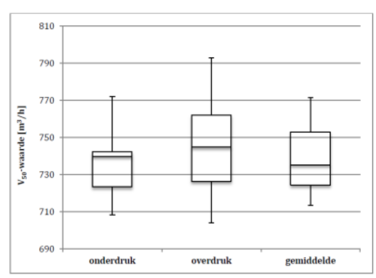
INTRODUCTION

- Airtightness important to meet energy performance requirements
- Increasing number of new houses with airtightness test
- Result of test may have financial consequences (fines, subsidies)
- Reliability of test?
- Long-term performance of airtightness, specifically for airtight houses?

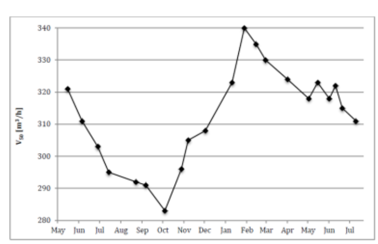
GHENT UNIVERSITY

LITERATURE REVIEW

- Repeatability (EN13829, method A)
  - St. deviation: 2%
  - Max. variation: 4%
- Reproducability (EN13829, method A)
  - St. deviation: 3%
  - Max. variation: 8%
- Seasonal variation
  - Max. variations: 18%
  - Swelling-shrinkage of wood
- Durability
  - No conclusive results



(Delmotte and Laverge 2011)



(Kim and Shaw 1986)

GHENT UNIVERSITY

OUTLINE

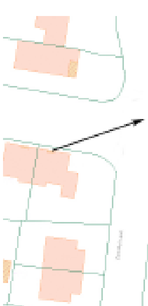
- Introduction
- **Test repeatability and seasonal variations**
- Durability of airtightness
- Conclusions

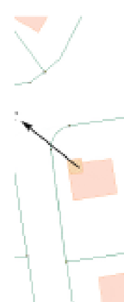
GHENT UNIVERSITY

TEST OBJECTS

- Semi-detached passive show house
- Masonry construction
- ACH_{50} = 0.55 (°2009)

- Detached passive show house
- Woodframe construction
- ACH_{50} = 0.21 (°2009)





GHENT UNIVERSITY

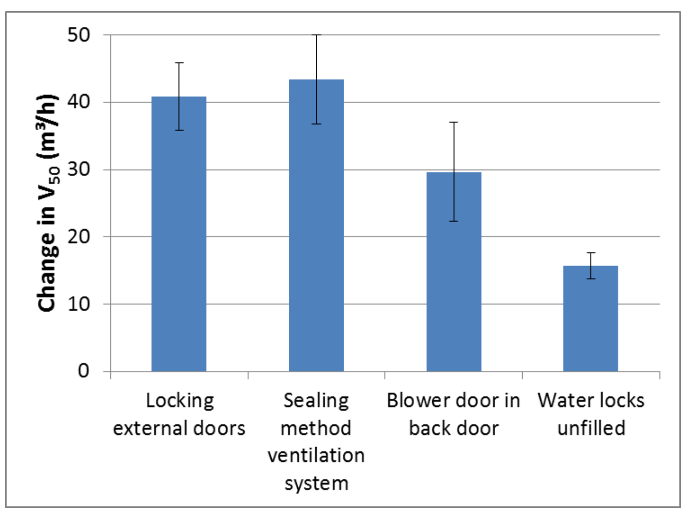
INFLUENCE OF BUILDING PREPARATION

- EN13829: room for interpretation
  - locking of external doors
  - disconnecting the ventilation system: central or decentral air supply/exhaust
  - position of blower door
- filling water locks

GHENT UNIVERSITY

INFLUENCE OF BUILDING PREPARATION

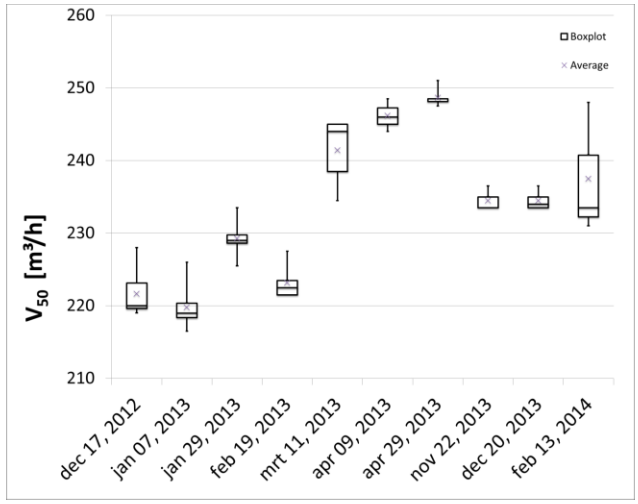
- Apparently small differences in preparation
- Relatively large impact on measured leakage in passive houses
- ΔV_{50} of 50 m³/h represents 20 to 35% change in ACH50



GHENT UNIVERSITY

REPEATABILITY AND SEASONAL VARIATION MASONRY HOUSE

- 10 days in 15 months
- 58 tests in total
- Repeatability in line with literature
    - Day 1: 12 measurements
    - Stdev: 1%, max var: 4%
- Variation result of changes in ductwork connections?



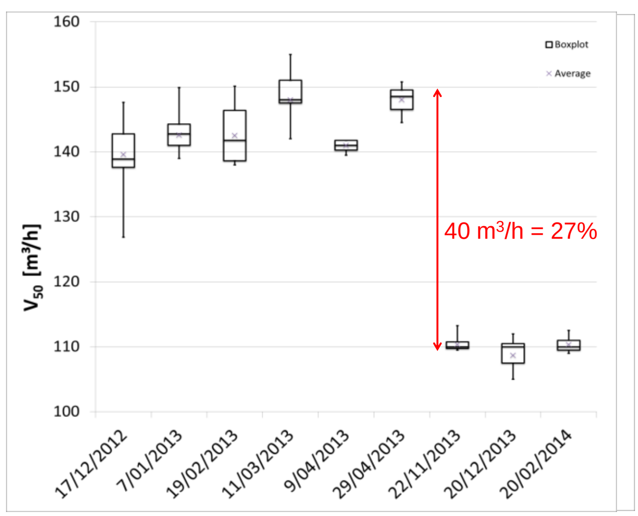
GHENT UNIVERSITY

9

9

REPEATABILITY AND SEASONAL VARIATION MASONRY HOUSE

- 9 test days in 15 months
- 53 tests in total
- Repeatability in line with literature
    - Day 2: 12 measurements
    - Stdev: 2%, max var: 5%
- No seasonal variation



GHENT UNIVERSITY

10

10

OUTLINE

- Introduction
- Test repeatability and seasonal variations
- **Durability of airtightness**
- Conclusions

GHENT UNIVERSITY

11

TEST OBJECTS FOR ANALYSIS OF DURABILITY

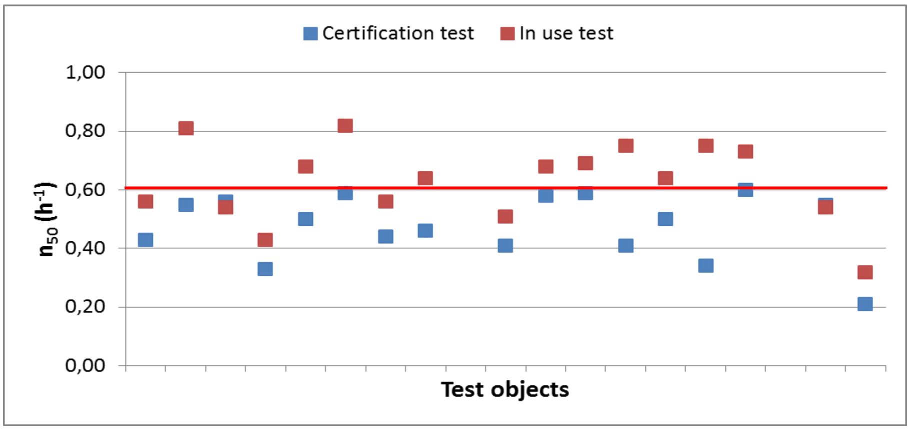
- 15 inhabited dwellings from passive house estates
  - +2 show houses
- Semi-detached and terraced masonry construction
- Age 3 - 27 months
- New test results compared to original certification tests

GHENT UNIVERSITY

12

DURABILITY OF AIRTIGHTNESS

- Average increase in air leakage by 32%
- Workmanship reproducibility: stdev original measurements = 19%



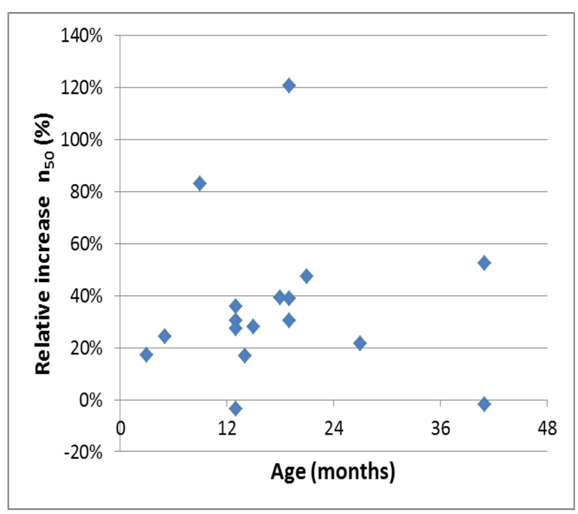
GHENT UNIVERSITY

13

13

DURABILITY OF AIRTIGHTNESS: RELATIVE INCREASE

- No significant relation with age
- Part of increase might be explained by differences in building preparation
  - Ventilation systems
  - Locking doors
- Observed leakage
  - Operable doors
  - Service penetration



GHENT UNIVERSITY

14

CONCLUSIONS

- Study on air leakage in extremely airtight houses
- Relative repeatability intervals in line with literature
  - More specific building preparation guidelines needed for better reproducibility of ambitious leakage requirements
- No clear evidence of seasonal variation of air leakage
- Long-term performance of airtightness
  - 90% of houses showed larger leakage over time
  - Relative degradation of airtightness, but small in absolute values
  - Hard to exclude the impact of building preperation

GHENT UNIVERSITY

FACULTY OF ENGINEERING AND ARCHITECTURE

Wolf Bracke
Researcher

DEPARTMENT OF ARCHITECTURE & ENGINEERING
RESEARCH GROUP: BUILDING PHYSICS, CONSTRUCTION & CLIMATE CONTROL

E wolf.bracke@ugent.be
T +32 9 264 37 52

Ghent University
@ugent
Ghent University

www.ugent.be

GHENT UNIVERSITY

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

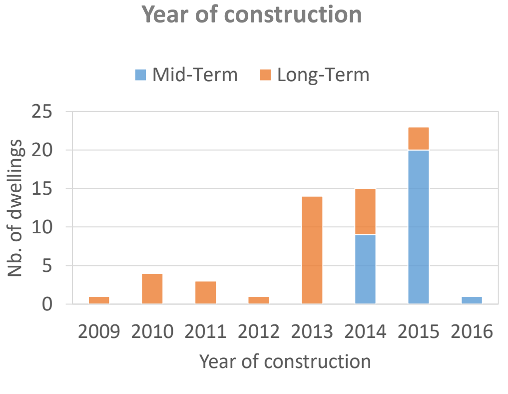
- MT and LT measurement campaigns based on two samples of single-detached low-energy dwellings:
  - ✓ *All dwellings measured upon completion* **[measurement n0]** *and treatment of airtightness well known*
- MT measurement campaign (1-3 years):
  - ✓ *Sample of 30 new single-detached dwellings*
  - ✓ *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*

Methodology

- 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* n_0 *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



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)

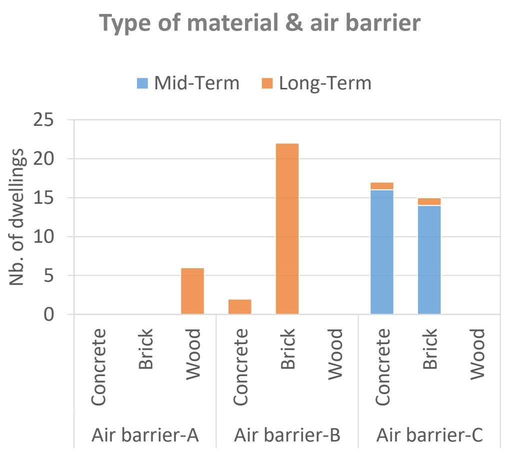
n2-n3 : 0.9 yr (from 0.4 to 1.7)

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



MT sample:

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

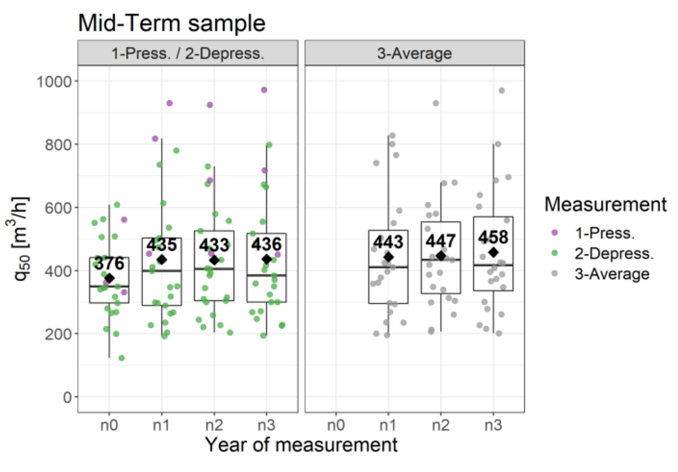
LT sample:

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}:

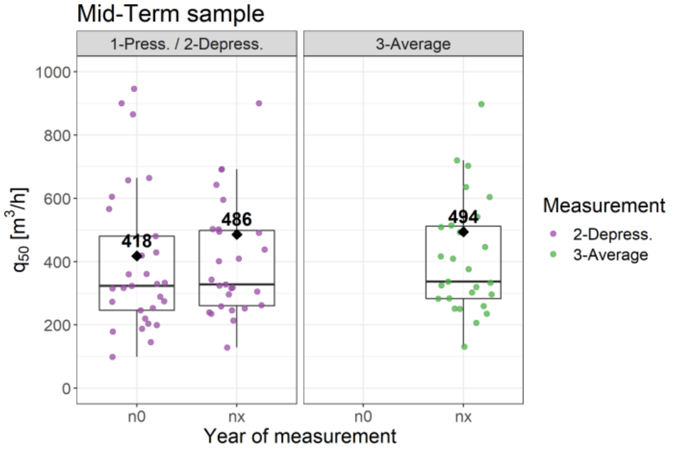
n0-n1: +58.9 $m^3.h^{-1}$ / +18%
(p-value = 0.037)
Timespan = 1.7 years

n0-n2: +57.2 $m^3.h^{-1}$ / +18%
(p-value = 0.026)
Timespan = 2.7 years

n0-n3: +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}:

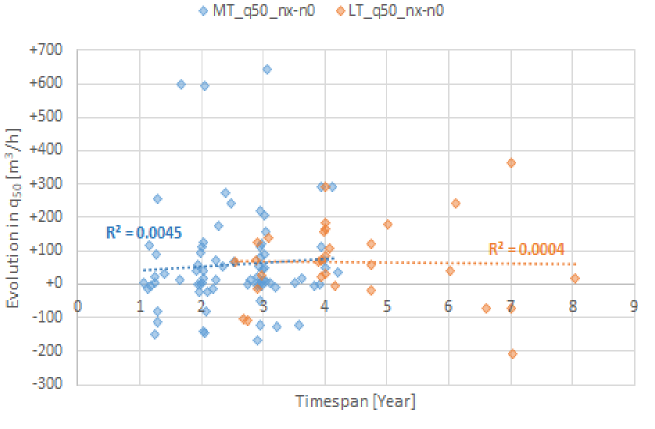
n0-nx: +67.7 $m^3.h^{-1}$ / +20%

(p-value = 0.002)

Timespan = 4.6 years

Evolution in q_{50} vs. Timespan

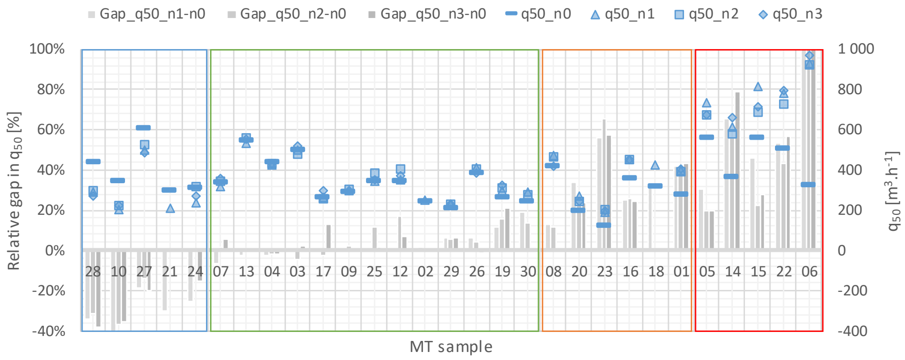
MT & LT samples



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



Δq_{50}<-50m³.h⁻¹ 5 houses

-50 <Δq_{50}<+50 13 houses

+50 <Δq_{50}<+150 6 houses

Δq_{50}>+150m³.h⁻¹ 5 houses

Analysis of explanatory factors

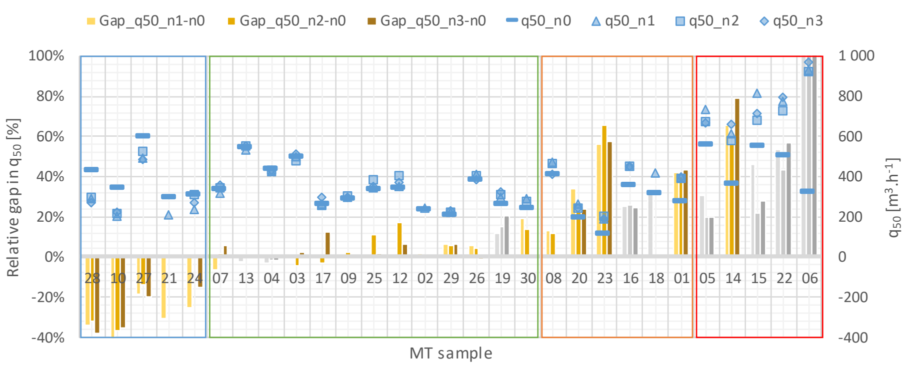
Nb. Of levels (MT)

1-storey (20)

2-storey (10)

2-storey houses seems to deteriorate more than 1-storey houses

→ Structural movement?



Δq_{50}<-50m³.h⁻¹ 5 houses

-50 <Δq_{50}<+50 13 houses

+50 <Δq_{50}<+150 6 houses

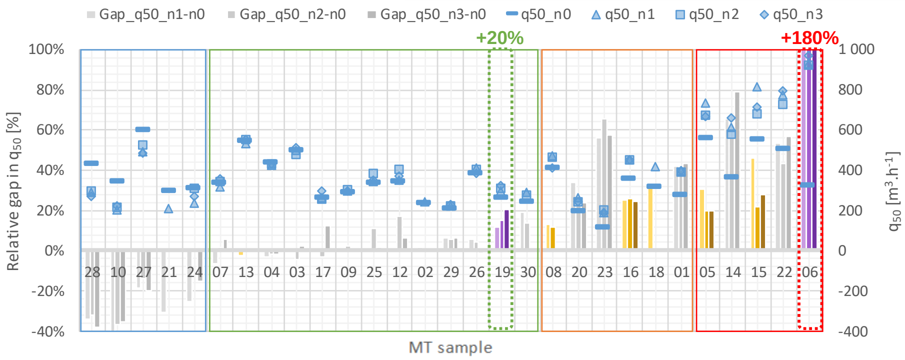
Δq_{50}>+150m³.h⁻¹ 5 houses

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?



Δq_{50}<-50m³.h⁻¹ — 5 houses

-50 <Δq_{50}<+50 — 13 houses

+50 <Δq_{50}<+150 — 6 houses

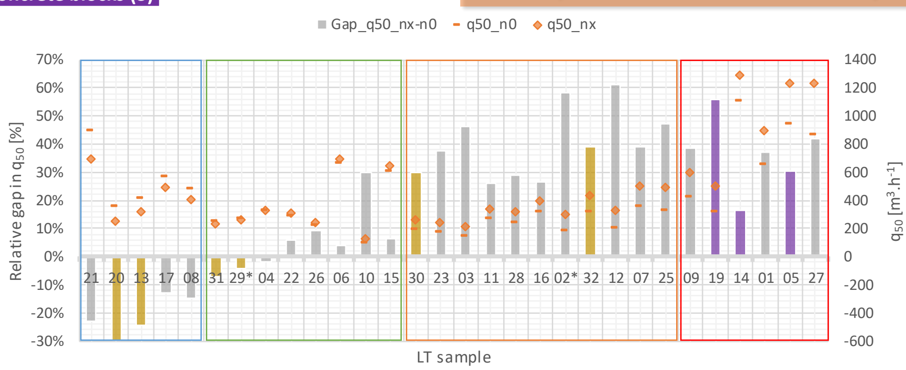
Δq_{50}>+150m³.h⁻¹ — 5 houses

Analysis of explanatory factors

Type of material (LT)

Wood frame (6)
Hollow bricks (21)
Concrete blocks (3)

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



Δq_{50}<-50m³.h⁻¹ — 5 houses

-50 <Δq_{50}<+50 — 8 houses

+50 <Δq_{50}<+150 — 11 houses

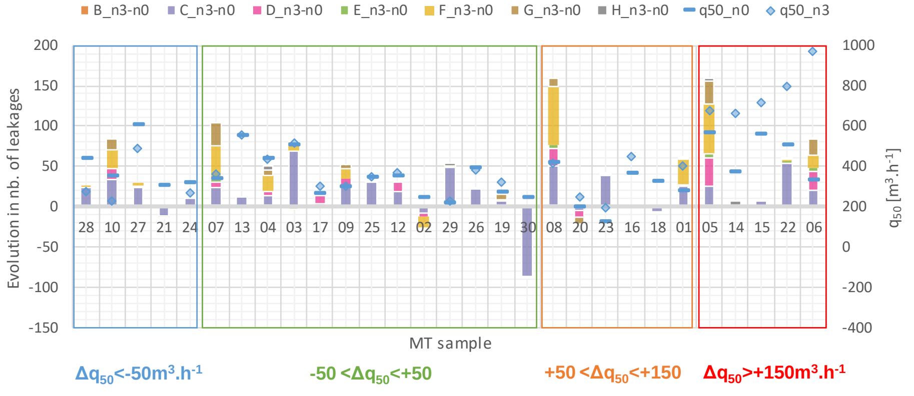
Δq_{50}>+150m³.h⁻¹ — 6 houses

Evolution of leakages

MT sample: n3-n0

B: junctions wall/slab
C: doors and windows
D: penetration through envelope
E: trapdoor
F: electrical components
G: junctions wall/window
H: other leakages

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/

Lauréat de l'Appel à Projets de Recherche 2015 « vers des Bâtiments Responsables à l'Horizon 2020 »

Cerema PLEIAQ CETII RESCOLL

avec le financement de ADEME