Airtightness of building components

Bias and Precision errors in the Measurement of Building Component Airtightness with Direct Component Test

Speaker
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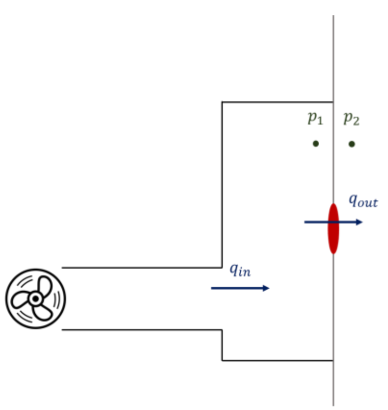
Direct testing of building components



At equilibrium:
q_{in} ➔ Δp constant
Δp ➔ q_{out}

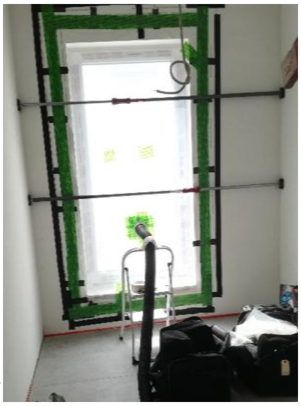
Hypothesis :
$q_{\text{in}} = q_{\text{out}}$

Experimental setup

- Pressure chamber
- Duct linking the fan to the chamber
- Manometer to measure airflows and pressure differences
- Computer for data processing
- Fan to pressurise or depressuise the chamber
- Calibrated disks to determine airflow

Range of measurement:
q_m = [0,17 ; 78,5] m³/h
Δp_m = [0 ; 2500] Pa

Different experimental designs



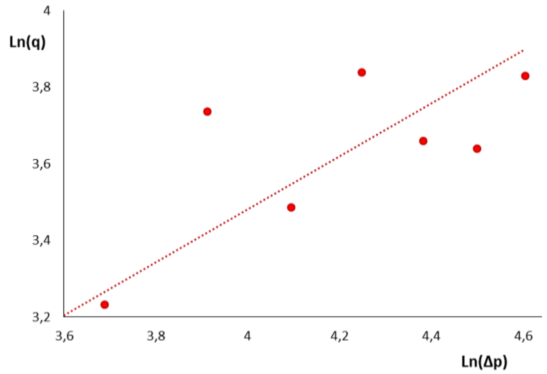
- Woodbox system
- Plastic-sheet system

Data processing (linear regression)

$q = C(\Delta p)^n$

$\ln(q) = n.\ln(\Delta p) + \ln(C)$

Slope (n) — Intercept (ln(C)) → $C_L = e^{\ln(C)} \left(\frac{T_0}{T_i}\right)^{1-n}$



$q_{50} = C_L(50)^n$

q_{50+} ; q_{50-} et q_{50m}

n_+ et n_-

OLS and WLOC

Experiments and methodology

① **Validation**

Large circular openings: $q = C_d\, A \sqrt{(2\Delta p)/\rho}$ **VS** *"In-situ"* measurement: $q = C_L(\Delta p)^n$

② **Bias errors**

Background leakage: airflow through the pressure chamber.

③ **Precision errors**

Repeatability tests:
- Direct with plastic sheet system
- Direct with wood-box system
- Direct with wood box system vs. indirect

Repeatability tests:
Multiple measurements on the same component conducted with the same equipment and by the same operator.

$u(y) \approx \sigma$

$e(\sigma) = (2[N-1])^{-0,5}$

Validation and background leakage

① and ②

	Calibrated Openings		Direct Component Test						
	A	q_{50}	$C_{L,+}$	n_+	$q_{50,+}$	$C_{L,-}$	n_-	$q_{50,-}$	q_{50}
Opening 1	1.76	3.54	0.55	0.48	3.73	0.55	0.49	3.78	3.76
Opening 2	3.46	6.93	1.05	0.49	7.24	1.02	0.50	7.10	7.17
Opening 3	7.07	14.15	2.21	0.48	14.48	2.10	0.49	14.23	14.36
Opening 4	13.85	27.73	3.99	0.49	27.62	4.14	0.49	28.39	28.01

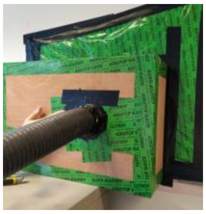
Δ_{max} in m³/h : 0,28 m³/h

Δ_{max} in % : 6,0 %

- Measurement error (random)
- Background leakage (systematic)

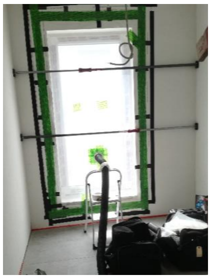
Background leakage:
measurement of a perfectly airtight component ($q_{50} \approx 0$).

$\delta q_b = 0{,}17$ m³/h at 50 Pa



Repeatability of direct component testing

③



10 tests using the plastic-sheet system
wood window + interface with wall

➡ $u = 10\ \%\ (q_{50m})$; $4\ \%\ (n_+)$ and $10\ \%\ (n_-)$
$q_{50} = 0{,}56$ m³/(h.m) ; $n_+ = 0{,}85$ and $n_- = 0{,}81$

20 tests using the wood-box system
electrical outlet

➡ $u = 5\ \%\ (q_{50m})$; $3\ \%\ (n_+)$ and $2\ \%\ (n_-)$
$q_{50} = 0{,}84$ m³/h ; $n_+ = 0{,}69$ and $n_- = 0{,}69$

Comparison between direct et indirect methods

③

$q_{50,1}$; $u(q_{50,1})$

$q_{50,2}$; $u(q_{50,2})$

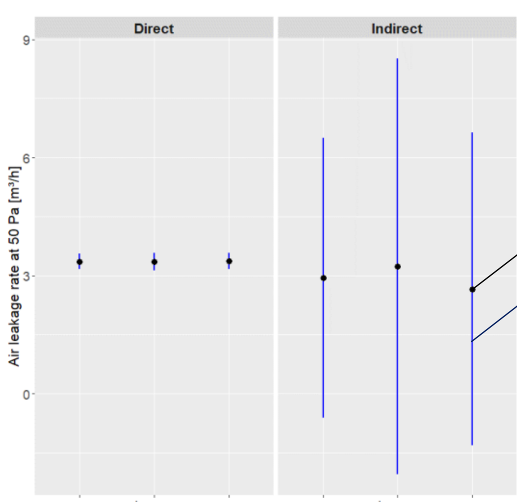
$$q_{50,c} = q_{50,2} - q_{50,1}$$

$$u(q_{50,c}) = \sqrt{u^2(q_{50,1}) + u^2(q_{50,2}) + 2\, r_{q_{50,1},q_{50,2}}\, u(q_{50,1})u(q_{50,2})}$$

Component measured:	Electrical outlet in a laundry room.
Direct testing:	20 tests using the woodbox system
Indirect testing:	20 tests of a limited zone (the laundry room) with an air leakage rate at 50 Pa ≈ 80 m³/h

Results of the comparison

③



Mean of 20 tests

≈ 95% Confidence interval (2* standard deviation)

Direct method:
q_{50} = [3,16 ; 3,56] m³/h (u = 3 %)

Indirect method:
q_{50} = [0,0 ; 6,5] m³/h (u = 60,5 %)

Conclusions

The direct component test measures *in-situ* n and C values of building components with high reliability (between 3% and 10%, depending on the chamber design).

But:
- Must be replicated when measuring multiple components.
- Requires different pressure chambers depending on the component measured.
- Uses another equipment than the fan pressurisation test.

Most promising applications:
- Guarantee of good installation.
- Intermediate testing earlier in the construction process.
- Improving databases with reliable *in-situ* values including n.

Further work:
- Validation on components with $n > 0,5$.
- Study variables influencing uncertainty.
- Increase the upper limit of range of measurement (doors).

Jacques Delens