Module 14
Structural Air Tightness

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- 14.1 Infiltration
- 14.2 Quantifying air leakage
- 14.3 Air pressurisation test
- 14.4 Air permeability standards
- 14.5 Air permeability of existing buildings
- 14.6 Improving air tightness

Module 14.1 Infiltration

On completion of this module learners will be able to:

- Explain the mechanisms that drive infiltration
- Identify infiltration paths

Air Infiltration

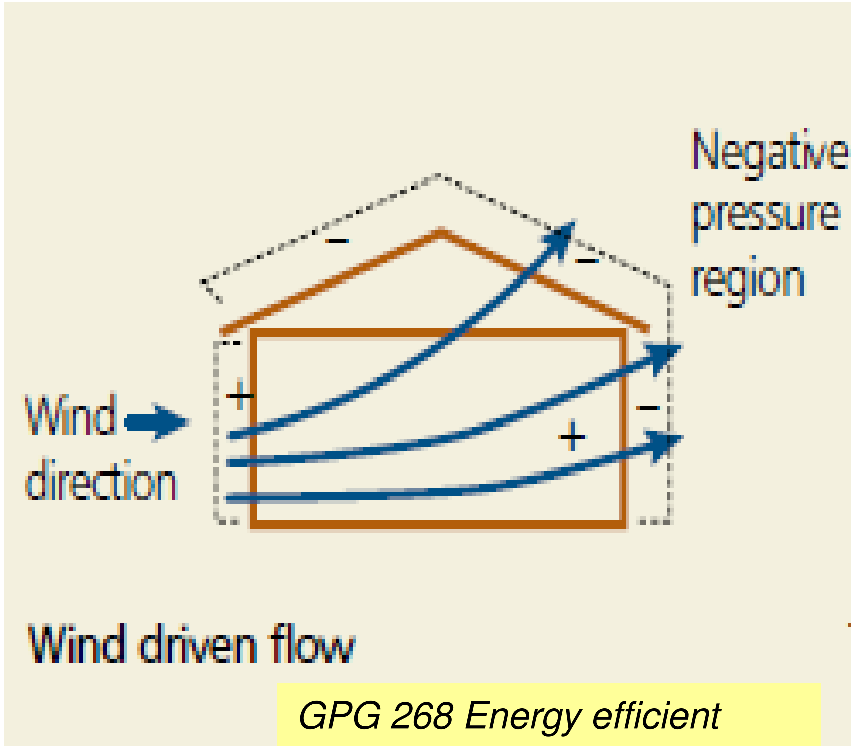
Definition

Uncontrolled entry of fresh air into a dwelling though air leakage paths in the building

Driving forces

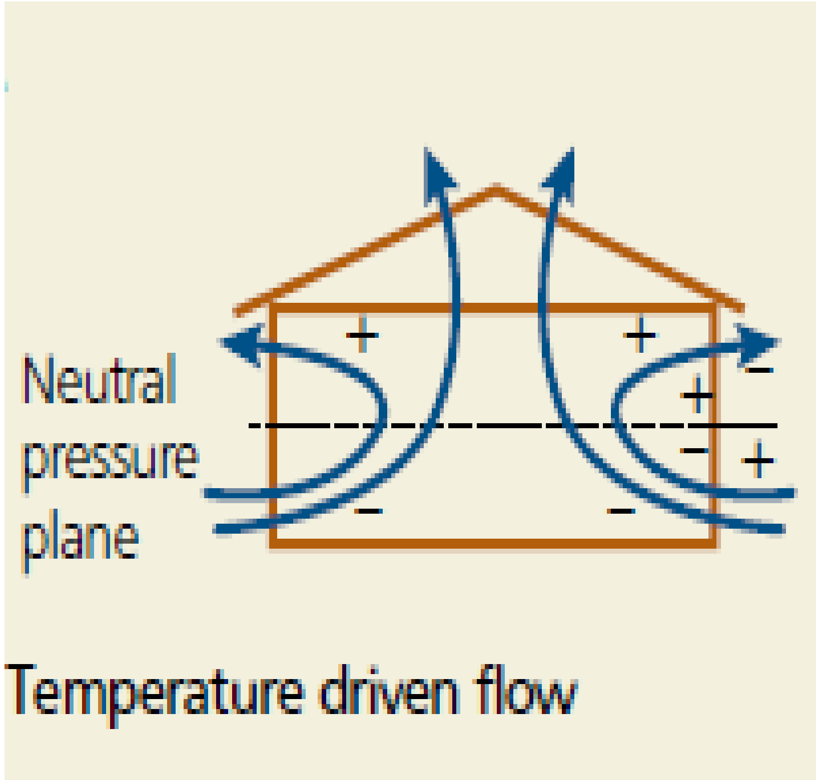
Caused by pressure differences and stack effects

- Pressure differences (Δ P)
- Airflow over a building causes regions of high pressure and low pressure
- High pressure on leeward side
- Low pressure on downwind side
- ΔP forces air through ventilation openings and air leakage paths in the fabric



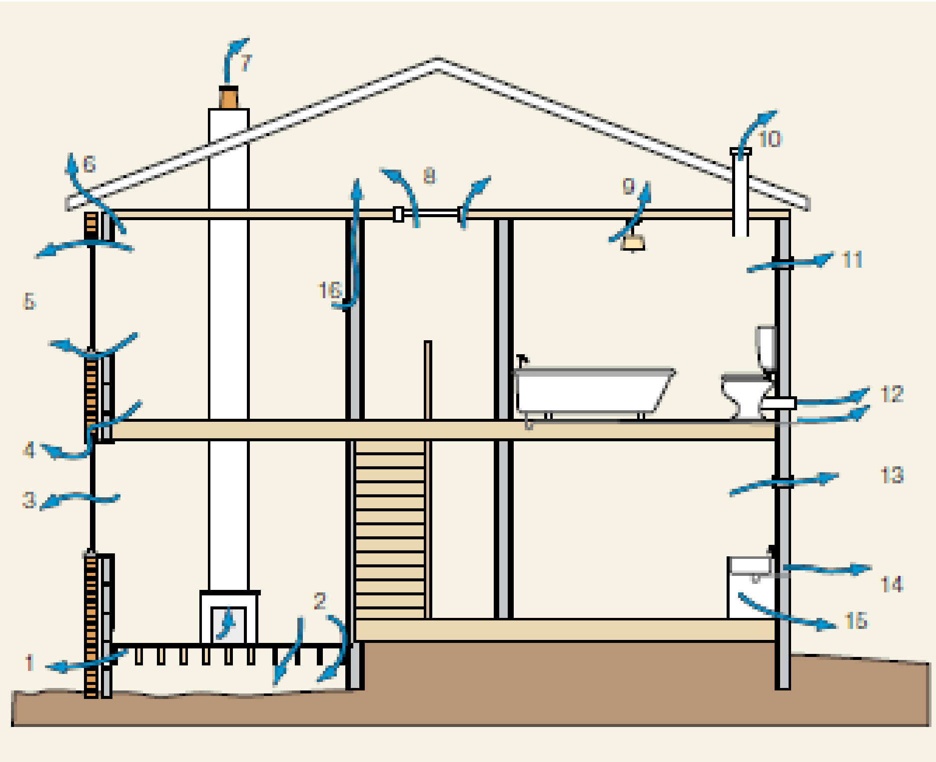
GPG 268 Energy efficient ventilation in dwellings (Energy Saving Trust)

- Temperature Differences (ΔT)
- Warm air is lighter than cold air (less dense) and rises.
- Warm air rises to the top of building and exits.
- Colder outside air enters at low level.
- Also known as the "stack effect".



GPG 268 Energy efficient ventilation in dwellings (Energy Saving Trust)

Air Leakage Paths



Most common air leakage paths

1 Underfloor ventilator grilles.
2 Gaps in and around suspended timber floors.
3 Leaky windows or doors.
4 Pathways through floor/ceiling voids into cavity walls and then to the outside.
5 Gaps around windows.
6 Gaps at the ceiling-to-wall joint at the eaves.
7 Open chimneys.
8 Gaps around loft hatches.
9 Service penetrations through ceilings.
10 Vents penetrating the ceiling/roof.
11 Bathroom wall vent or extract fan.
12 Gaps around bathroom waste pipes.
13 Kitchen wall vent or extractor fan.
14 Gaps around kitchen waste pipes.
15 Gaps around floor-to-wall joints (particularly with timber frame).
16 Gaps in and around electrical fittings in hollow walls.

Air Leakage paths from GPG268 page 7

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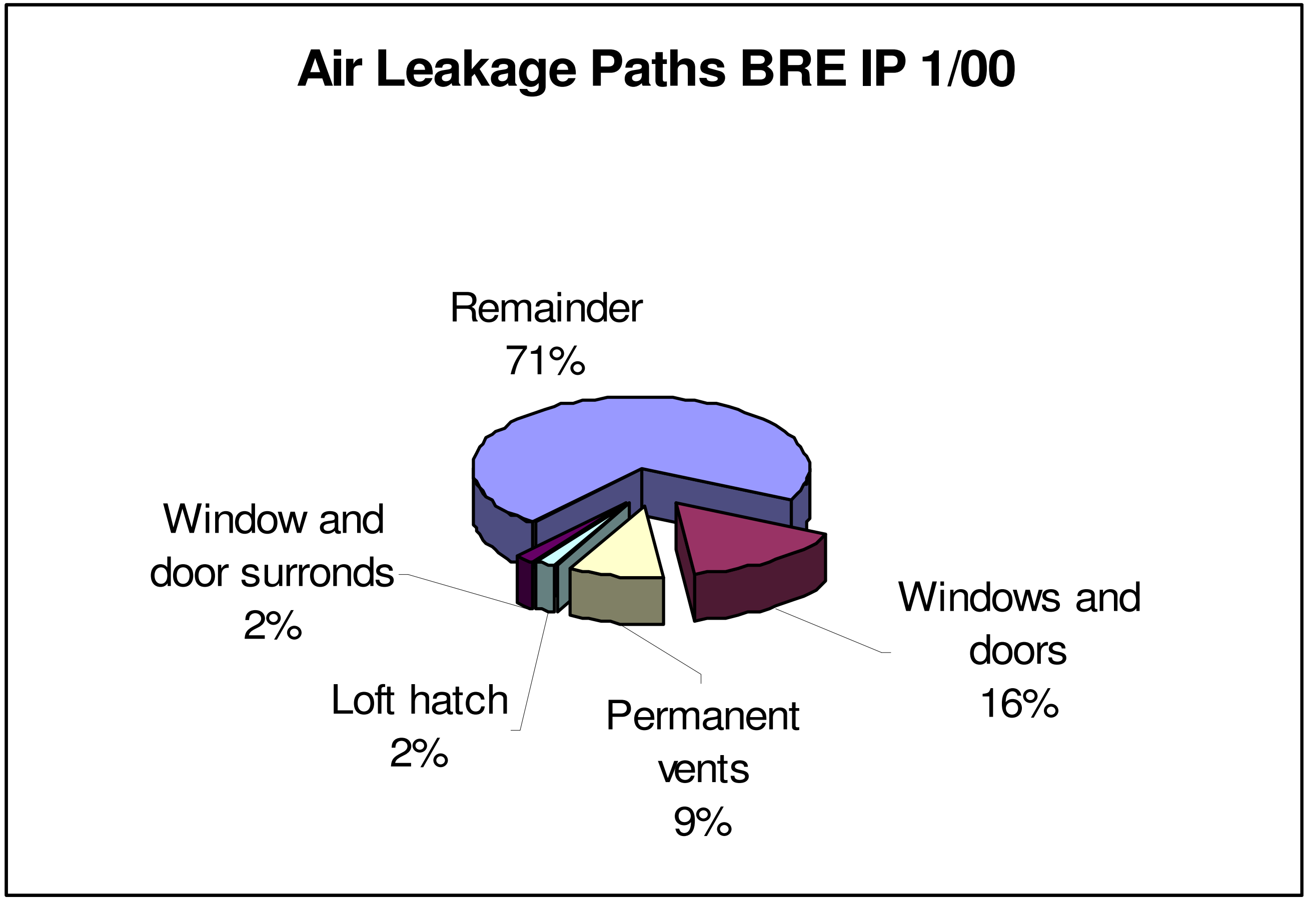

Air Leakage Paths BRE IP 1/00
Remainder 71%
Window and door surronds 2%
Loft hatch 2%
Permanent vents 9%
Windows and doors 16%

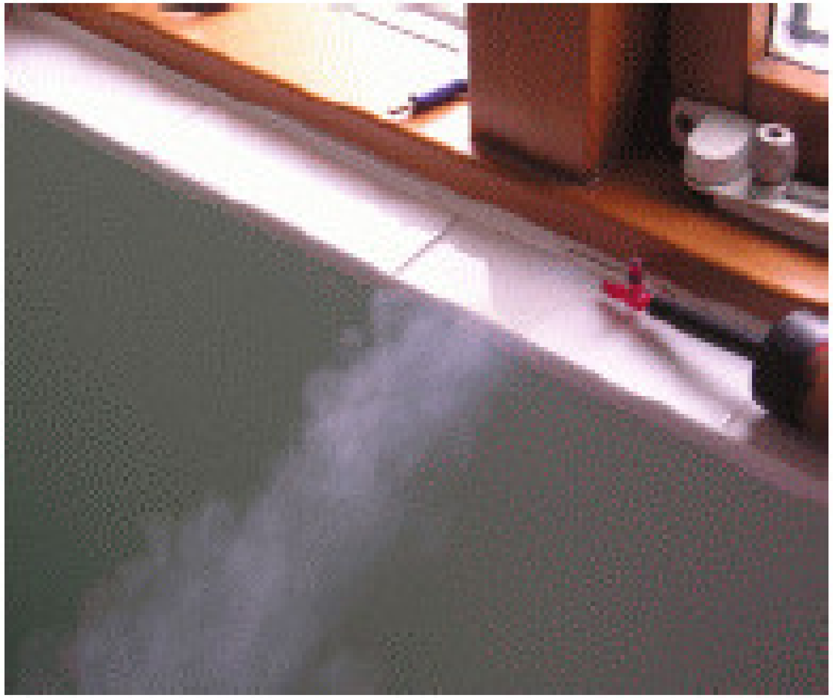
- Remainder 71%
  - Plasterboard dry lining on dabs or battens
  - Cracks, gaps and joints in the structure
  - Joist penetrations of external walls
  - Timber floors (under skirting and between boards)
  - Junctions between internal stud walls and with floors and ceilings
  - Electrical components such as sockets, switches & light fittings
  - Service entries & ducts
  - Areas of unplastered wall between intermediate floors, behind baths etc.

- Images of air leakage paths taken from three AVASH reports

Advanced Ventilation Approaches for Social Housing (AVASH) - Irish Sampling & Survey Report by Delap & Waller

Danish Sampling & Survey Report Compiled by Ole Balslev-Olesen, Cenergia Energy Consultants for the AVASH Project.

Advanced Ventilation Approaches for Social Housing (AVASH) - Irish Sampling & Survey Report by Delap & Waller



14.2 Quantifying Air Leakage

- On completion of this modules learners will be able to:
  - Define air permeability
  - List the common units used to quantify air permeability and convert between them

– Definition of Air Permeability

"The average volume of air that passes through one square meter of the building envelope when subject to a 50 Pascal pressure difference across the building structure"

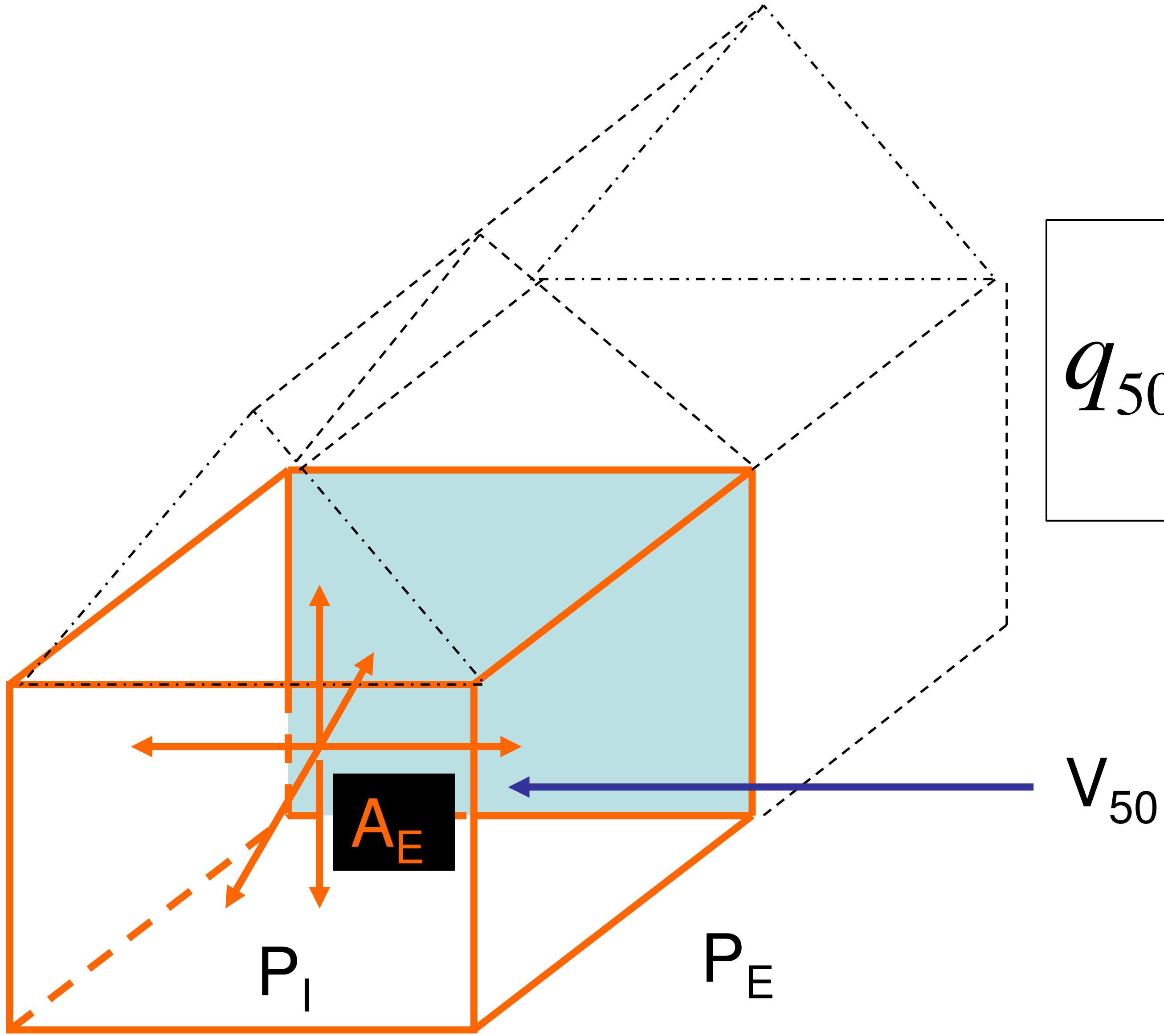
IS EN 138929:2000

q_{50} Air permeability @ 50 Pa $m^3/(h.m^2)$

V_{50} Air leakage rate @ 50 Pa m^3/h

A_E Area of the building envelope m^2

$$q_{50} = \frac{V_{50}}{A_E}$$



$$q_{50} = \frac{V_{50}}{A_E}$$

$$\Delta P = P_E - P_I = 50 \text{ Pa}$$

Units for permeability vary :

- Units for Permeability at 50 Pa can be expressed as $m^3/(h.m^2)$, $(m^3/h)/m^2$, $m^3h^{-1}m^{-2}$
- Permeability at 50 Pa can also be expressed as air changes per hour, which is the number of times the entire volume (V) of air within the house is replaced in 1 hour and is denoted as ACH, ach, ac/h or ach^{-1} or simply h^{-1}.
- To convert from permeability at 50 Pa expressed in $m^3/(h.m^2)$ to permeability at 50 Pa expressed in ach multiply by (A_E/V_E)

Example

A detached house measures 8m long by 7m deep by 5m high. The air permeability is measured as 3 $m^3/(h.m^2)$ at 50 Pa. Convert this to ACH at 50 Pa.

Solution

$A_E/ = 262\ m^2$

$V_E = 280\ m^3$

Air permeability $= (3)x(262/280)$

$= 2.8$ ACH at 50 Pa

Air permeability at normal pressure

- The air permeability measured in $(m^3/h)/m^2$ at 50 Pa can be approximated to air changes per hour under normal pressure by dividing by 20
- If the air permeability is measured as 3 $m^3/(h.m^2)$ at 50 Pa then the air permeability at normal working pressure would be approximately 0.15 air changes per hour.

14.3 Air Pressurisation Testing

- On completion of this module learners will be able to:
  - List the main standards applicable to air pressurisation testing
  - Describe the principles involved in air pressurisation testing

14.3 Air Pressurisation Testing

Methodology for undertaking an air pressurisation tests is covered in :

- EN 13829 Thermal performance of buildings – determination of air permeability of buildings – air pressurisation

- CIBSE TM23 Testing buildings for air leakage

Pressurisation Test method

- Preparation
  - Fan is fitted into doorway of the house
  - All adjustable openings are closed e.g. windows, doors, trickle vents
  - Intentional openings are sealed e.g. fire places, extract fans
  - Internal doors opened

Source: Air Tightness Testing of New Dwellings, BSRIA

- Testing

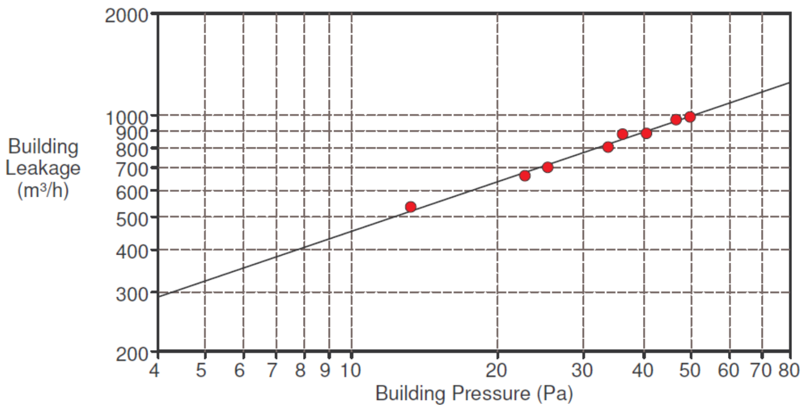
  - It is recommended that two sets of measurements are made: pressurisation and depressurisation
  - Measurements of air flow rate and indoor-outdoor pressure difference over a range of applied pressure differences increments of no more than 10 Pa
  - Highest pressure difference will be at least 50 Pa (recommended up to +/- 100 Pa)

- Results
- Test report shall contain the following:
  - Property details e.g. post address, date of construction
  - A reference to the testing standard
  - Test object e.g. building dimensions, floor area, volume, status of openings (sealed, open etc.), type of heating & ventilation system, documentation of calculations
  - Test data e.g. pressure readings, temperature readings, air leakage graph, air change rate at 50 Pa
  - Date of test

Test Results at 50 Pascals:	
V50: Airflow (m^3/h)	995 (+/- 1.1 %)
n50: Air Changes per Hour (1/h)	
w50:	
q50: $m^3/(h*m^2$ Surface Area)	4.97
Leakage Areas:	506.1 cm^2 (+/- 3.1 %) Canadian EqLA @ 10 Pa or 2.53 cm^2/m^2 Surface Area 312.1 cm^2 (+/- 5.3 %) LBL ELA @ 4 Pa or 1.56 cm^2/m^2 Surface Area
Building Leakage Curve:	Air Flow Coefficient (Cenv) = 147.4 (+/- 8.5 %) Air Leakage Coefficient (CL) = 147.4 (+/- 8.5 %) Exponent (n) = 0.488 (+/- 0.024) Correlation Coefficient = 0.99298

Test Standard:	EN 13829	Test Mode:	Depressurization
Type of Test Method:	B	Regulation complied with:	Building Regs Part L 2007
Equipment:	Model 4 (230V) Minneapolis Blower Door, S/N 12345		

Inside Temperature:	19 ℃	Volume:	
Outside Temperature:	20 ℃	Surface Area:	200 m^2
Barometric Pressure:	101325 Pa	Floor Area:	
Wind Class:	0 Calm	Uncertainty of Building Dimensions:	3 %
Building Wind Exposure:	Partly Exposed Building	Year of Construction:	2008
Type of Heating:	Gas		
Type of Air Conditioning:	None		
Type of Ventilation:	Natural; trickle vents		



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BUILDING LEAKAGE TEST Page 2

Date of Test: 25-6-08 Test File: Untitled

Comments

Data Points: Depressurization - Data Entered Manually

Nominal Building Pressure (Pa)	Fan Pressure (Pa)	Nominal Flow (m^3/h)	Temperature Adjusted Flow (m^3/h)	% Error	Fan Configuration
1.9	n/a				
-11.3	43.9	535	536	3.0	Ring B
-20.8	67.3	661	662	-2.2	Ring B
-31.8	99.7	804	805	-1.9	Ring B
-38.5	120.4	883	884	-1.4	Ring B
-47.8	150.9	987	989	-0.3	Ring B
-44.6	145.2	969	970	1.0	Ring B
-34.2	119.1	878	879	3.6	Ring B
-23.4	75.6	701	702	-1.7	Ring B
2.0	n/a				

Test 0 Baseline (Pa): p01- = 0.0 p01+ = 1.9 p02- = 0.0 p02+ = 2.0

14.4 Air Permeability Standards

- On completion of this module learners will be able to:
  - State the relevant standard for air permeability for their country and current acceptable value for air permeability.

14.4 Air Permeability Standards

Standard	Permeability $m^3/(h.m^2)$ @ 50Pa
UK 2010 (Oct)	8
Ireland TGDL 2008	10
Spain	
France	
Germany	
CIBSE TM23:2000 Nat Vent Good Practice Nat Vent Best Practice MVHR Good Practice MVHR Best Practice	 10 5 5 3

PassivHaus standard< 0.6 ach @ 50 Pa

14.5 Air permeability of existing buildings

- On completion of this module learners will be able to:
  - Quantify air permeability for existing buildings

14.5 Air permeability of existing buildings

AVASH is a project funded by Intelligent Energy Europe (IEE) Agency to assess performance of social housing in relation to insulation and air tightness

- Three partners
  - UK — University of Brighton UK
  - Ireland — Delap & Waller EcoCo Ltd., Cluid Housing
  - Denmark — Cenergia Energy Consutants, KAB Housing

- http://www.brighton.ac.uk/avash

AVASH Air tightness for 32 Irish Properties

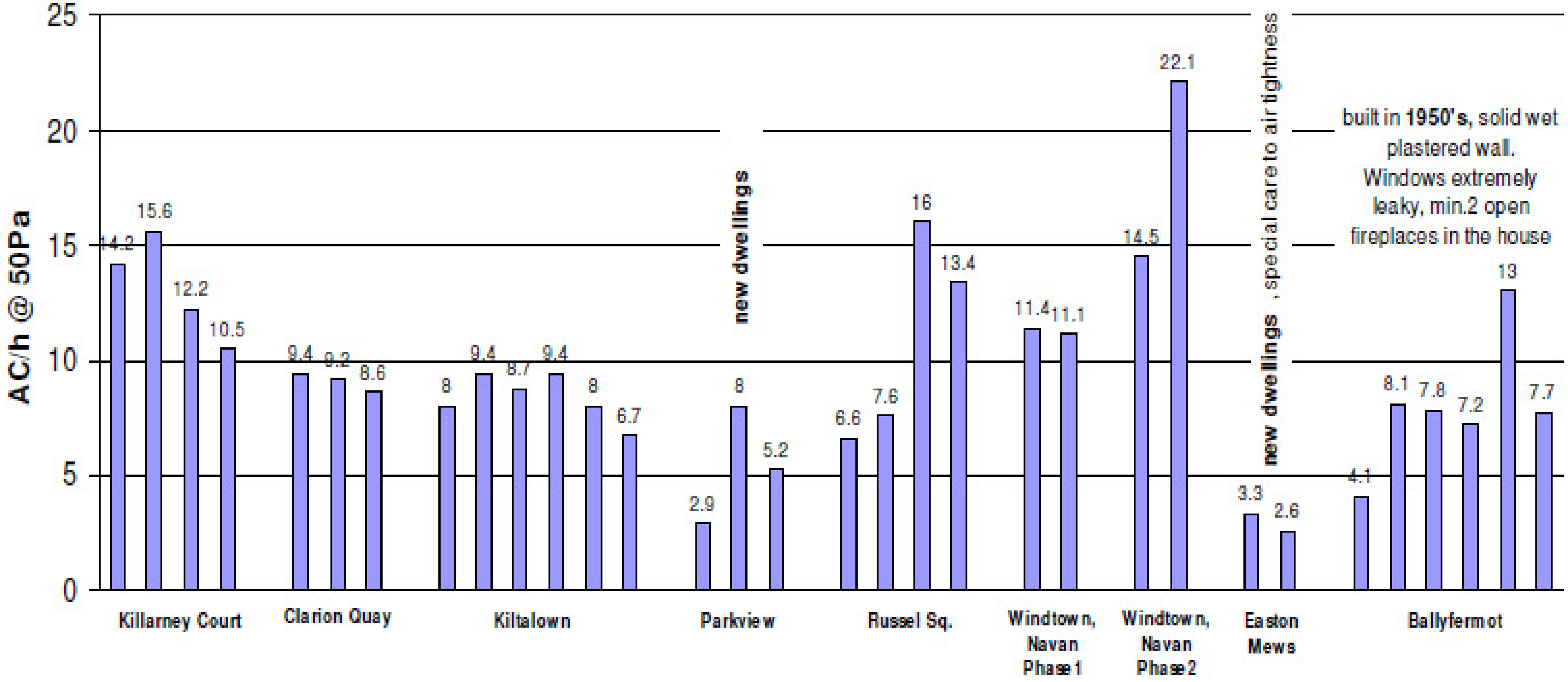


Fig 31 page 132 Advanced Ventilation Approaches for Social Housing (AVASH) - Irish Sampling & Survey Report by Delap & Waller
http://www.brighton.ac.uk/avash/downloads/iresampsurv/iresampsurvweb.pdf

An interesting point from the Irish Survey

- 1950's houses showed better performance to recently built houses!
  - 1950's 7.98 ac/h@50Pa
  - Newly built 10.36 ac/h@50Pa

- Reason
  - method of construction
  - solid wall construction, wet plastered

AVASH Air tightness for 18 UK Properties

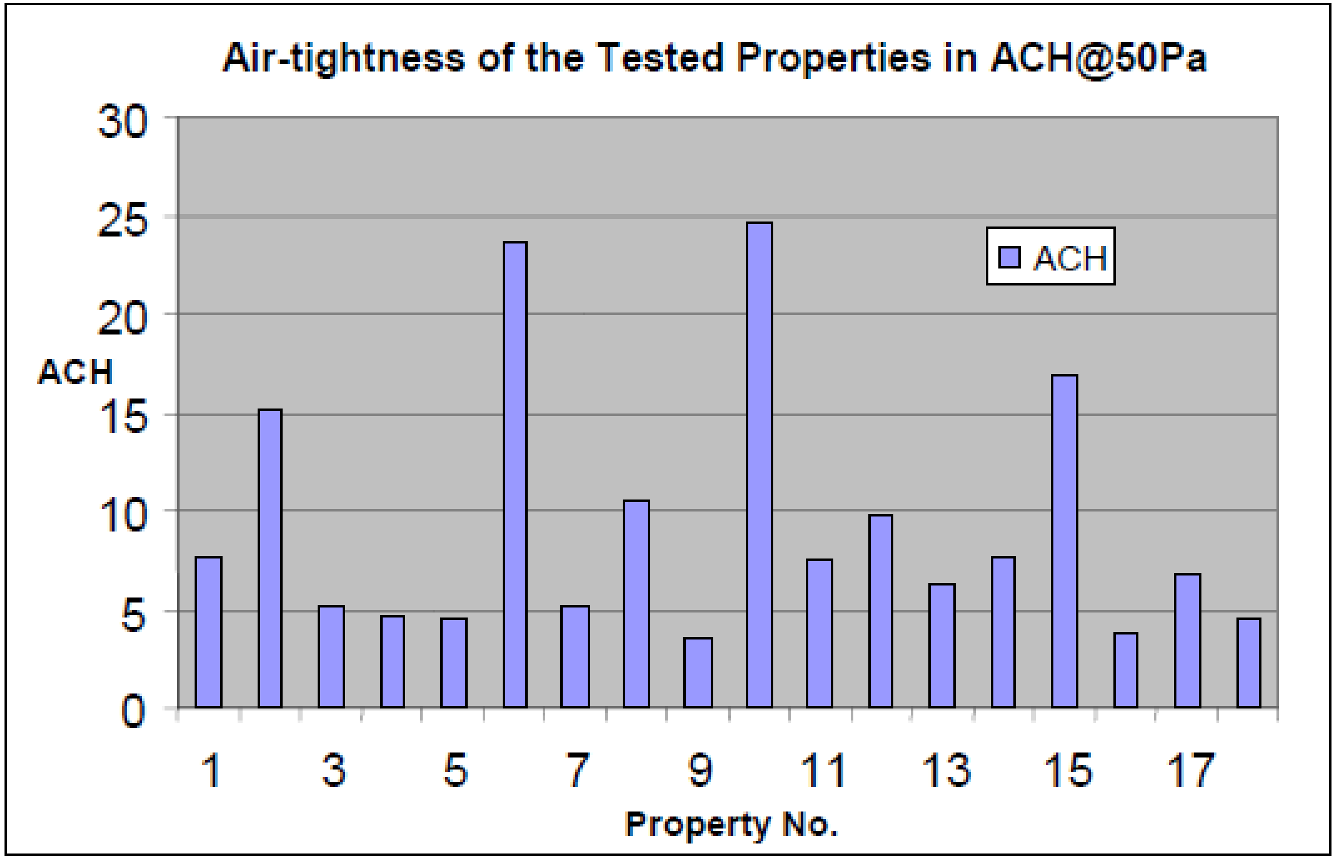


Fig 19.1 page 70 Advanced Ventilation Approaches for Social Housing (AVASH) - UK Sampling & Survey Report . University of Brighton. http://www.brighton.ac.uk/avash/downloads/uksampsurv/uksampsurv.pdf

AVASH Air tightness for 18 Danish Properties

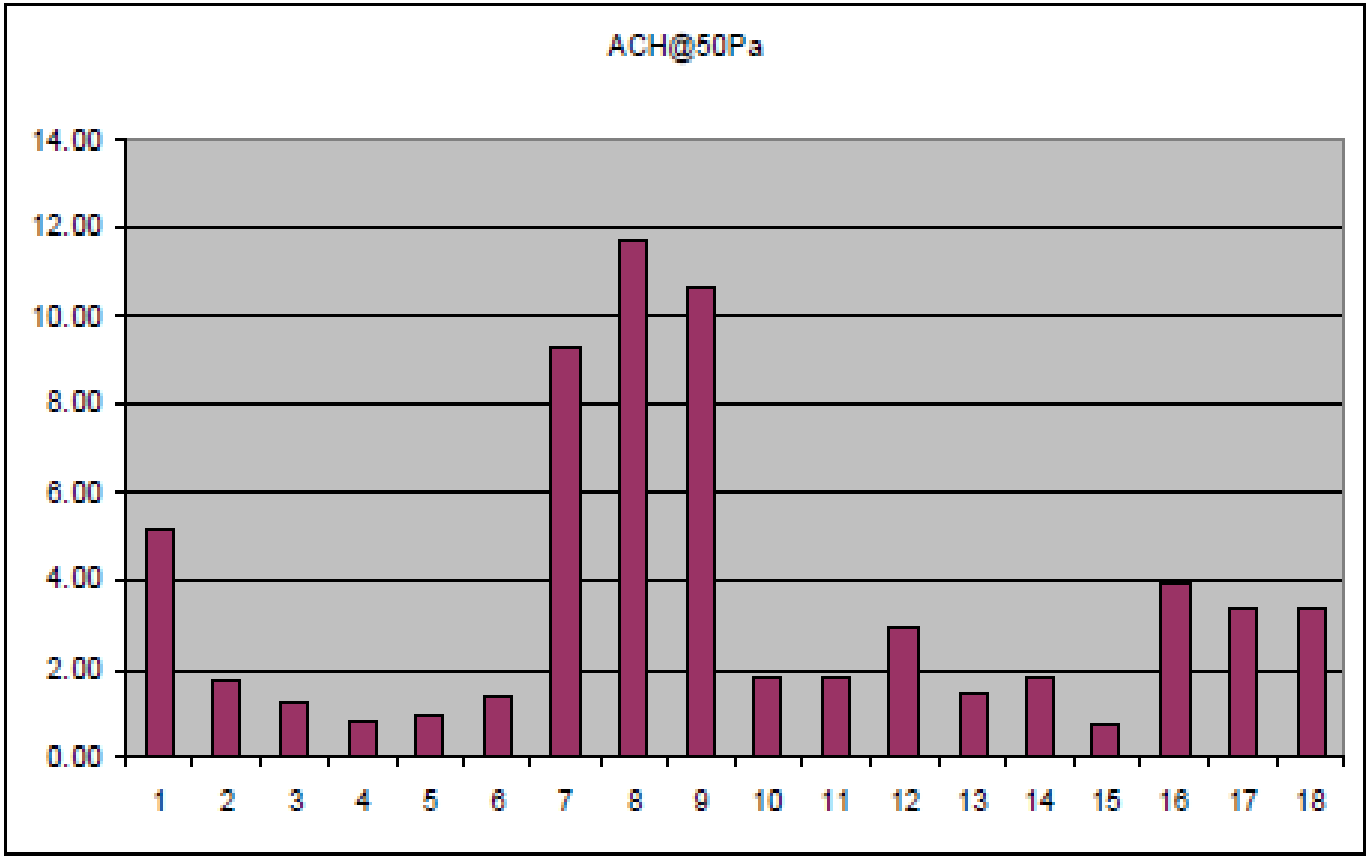
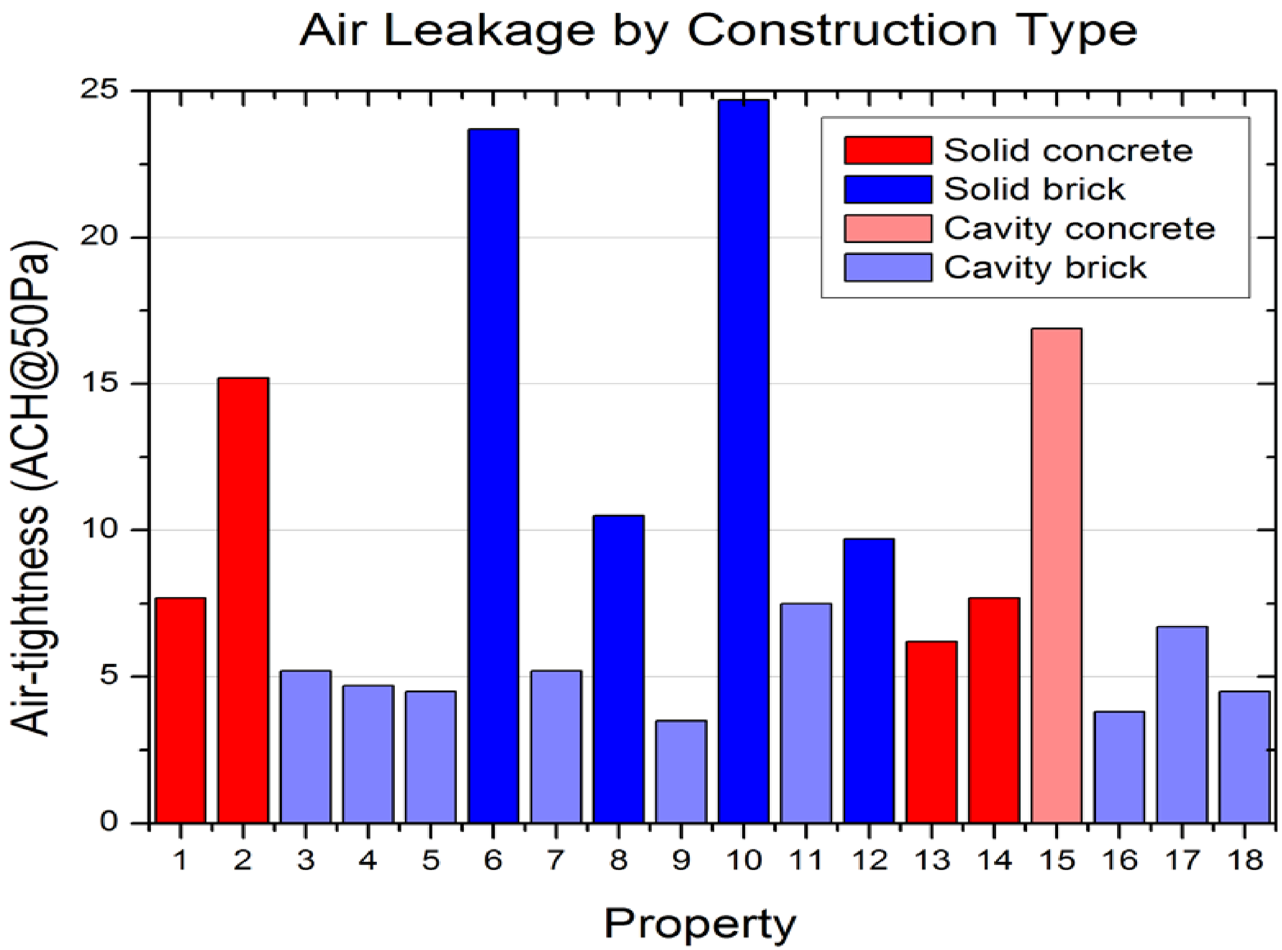


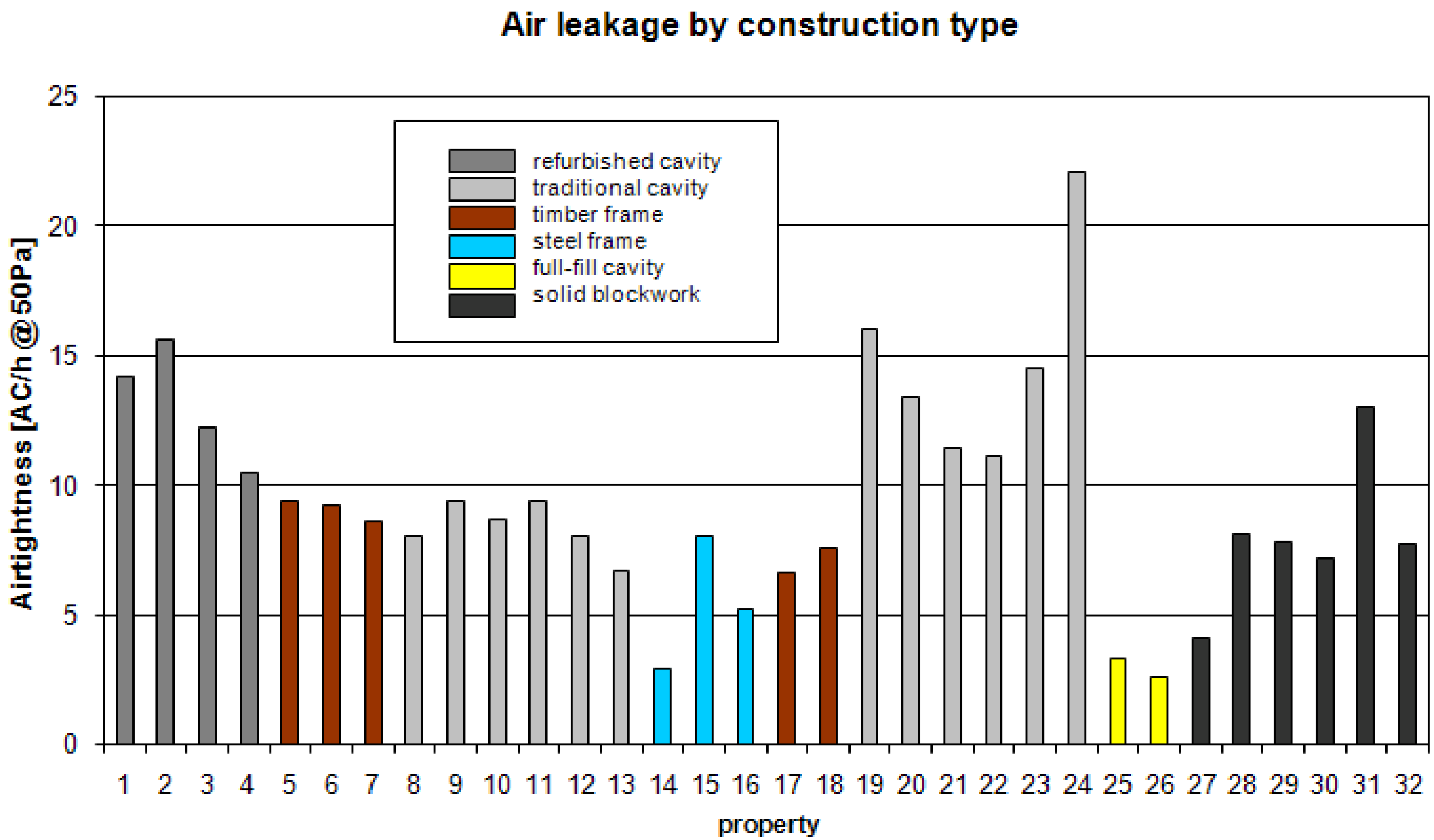
Figure 5 page 9 Danish Sampling & Survey Report Compiled by Ole Balslev-Olesen, Cenergia Energy Consultants for the AVASH Project.
http://www.brighton.ac.uk/avash/downloads/densampsurv/densampsurv.pdf

AVASH Air Permeability by construction type UK



http://www.brighton.ac.uk/avash/avash_results.html

AVASH Air Permeability by construction type Ireland



http://www.brighton.ac.uk/avash/avash_results.html

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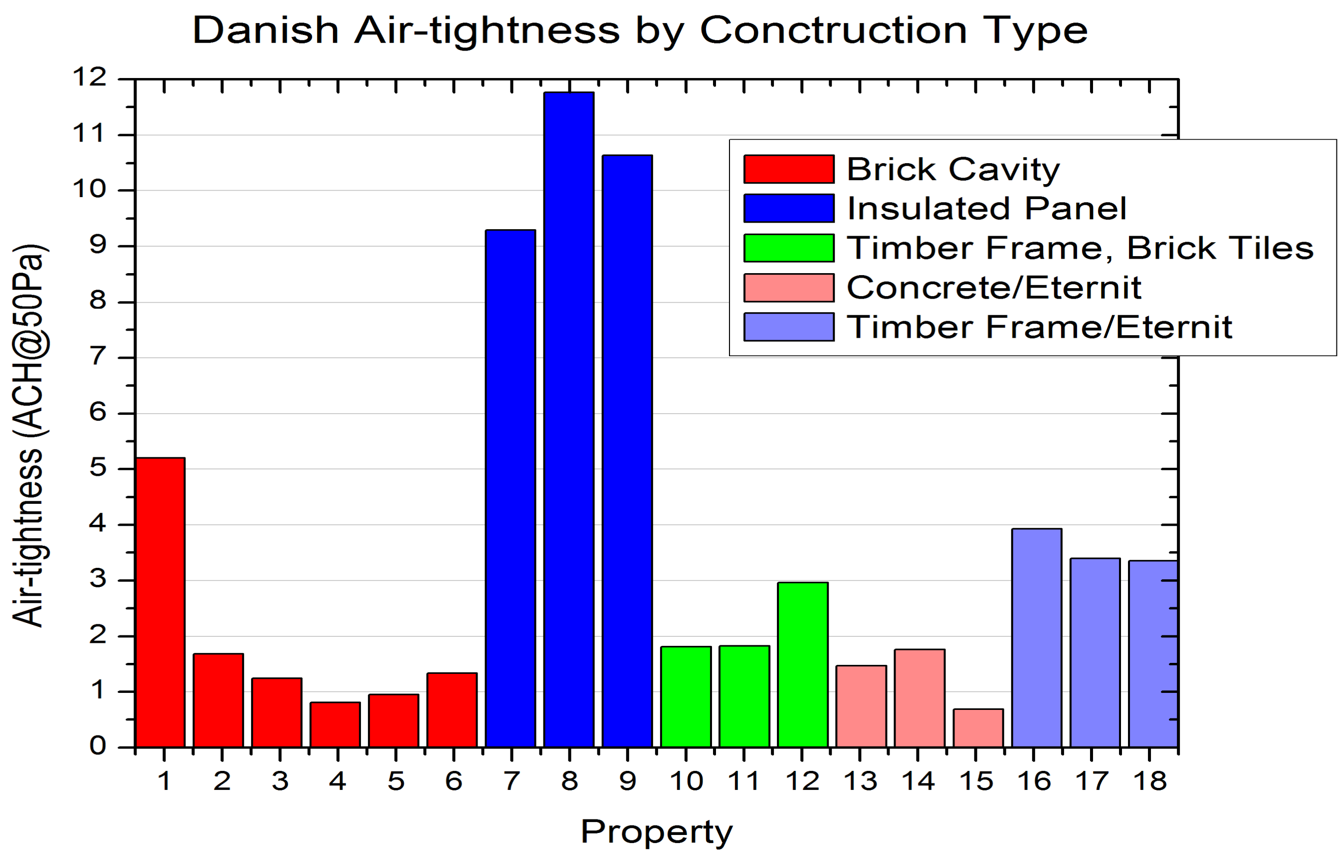
AVASH Air Permeability by construction type Denmark

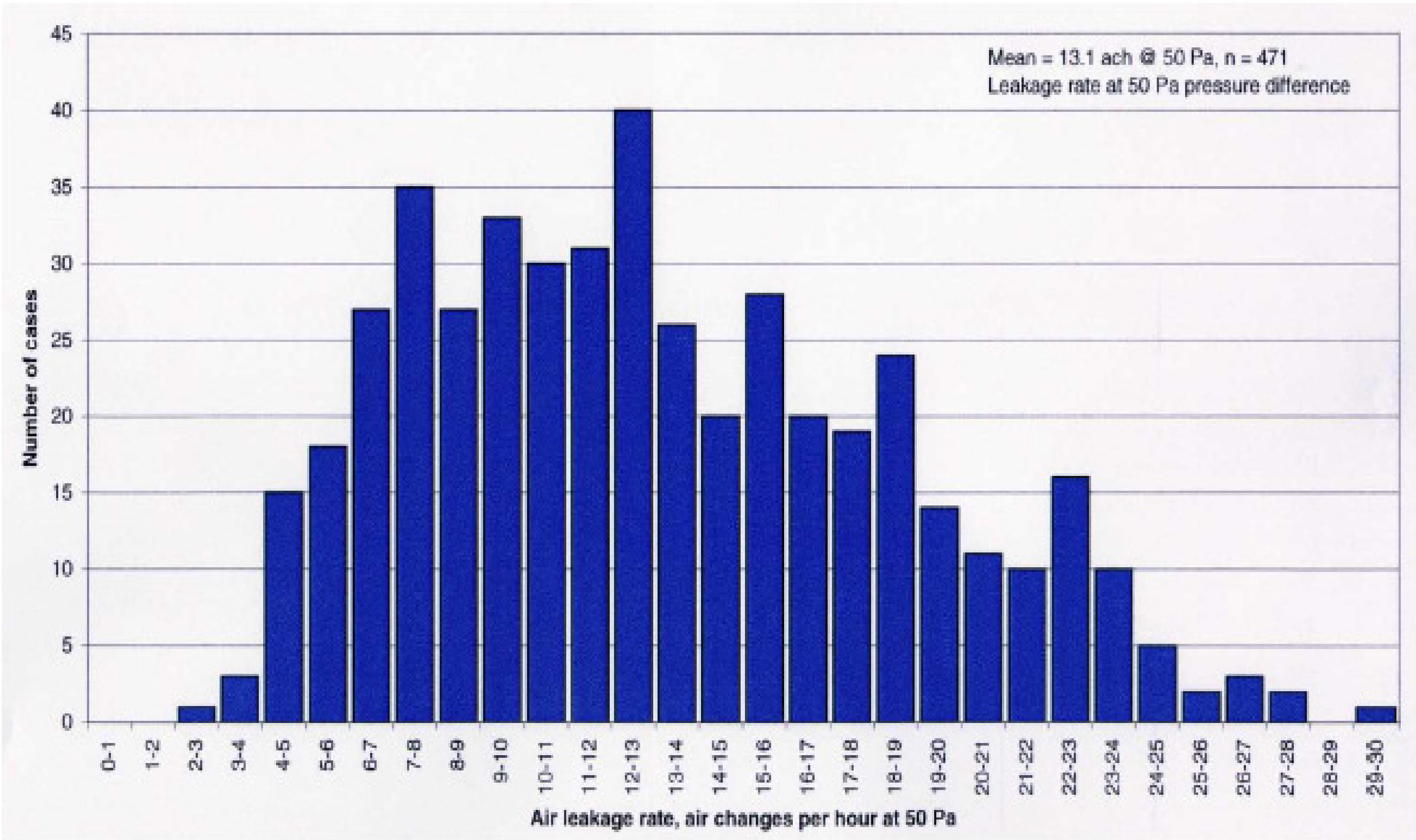


http://www.brighton.ac.uk/avash/avash_results.html

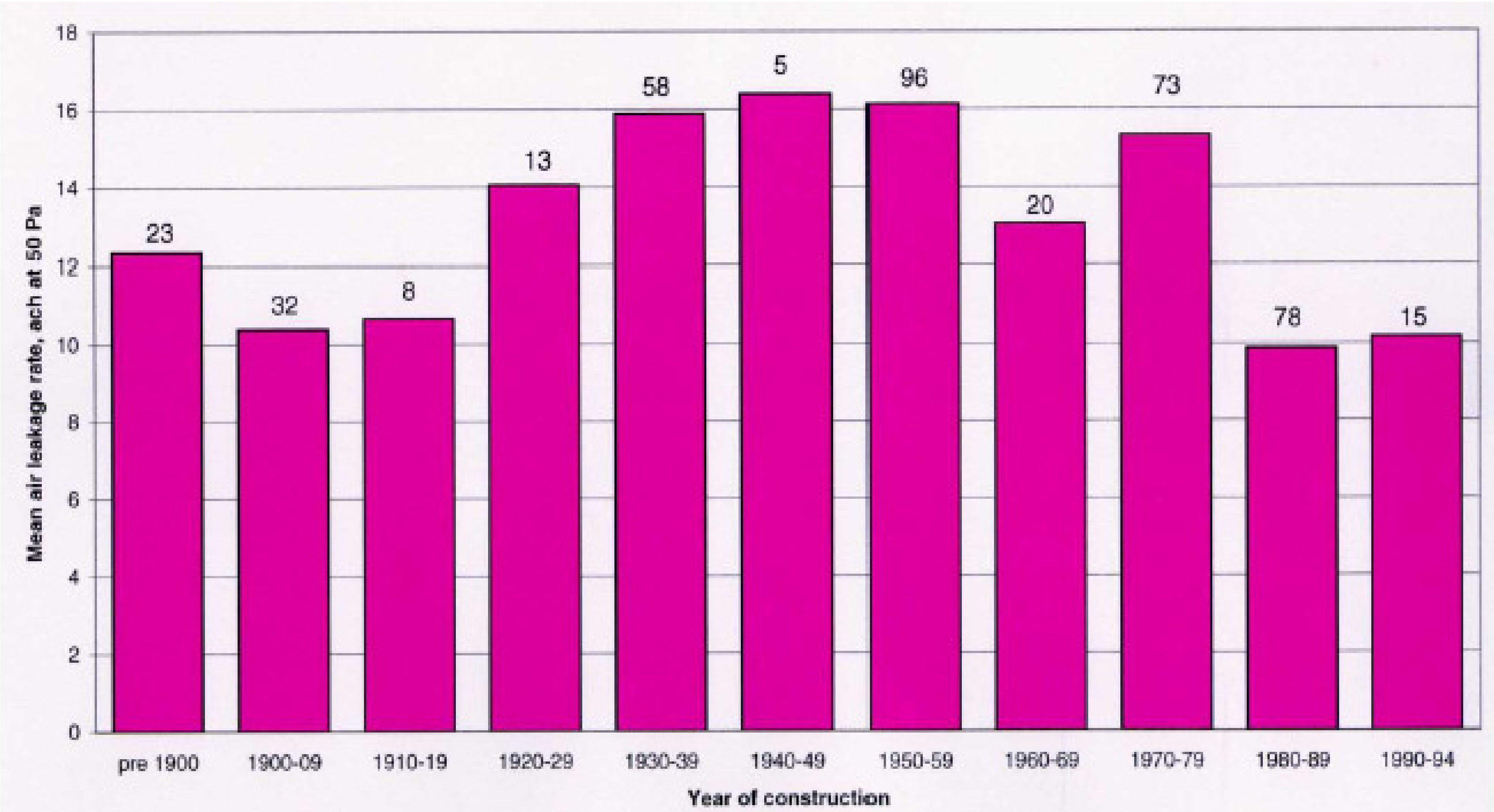
The BRE has a database of air permeability for 471 dwellings and 87 flats (constructed from large panel systems LPS)

- Analysis of data from this database is contained in IP 1/00 “Air Tightness in UK dwellings”
- The following 7 slides are based on this information paper

Air permeability in UK dwellings IP 1/00 BRE



Air permeability based on year of construction IP 1/00 BRE



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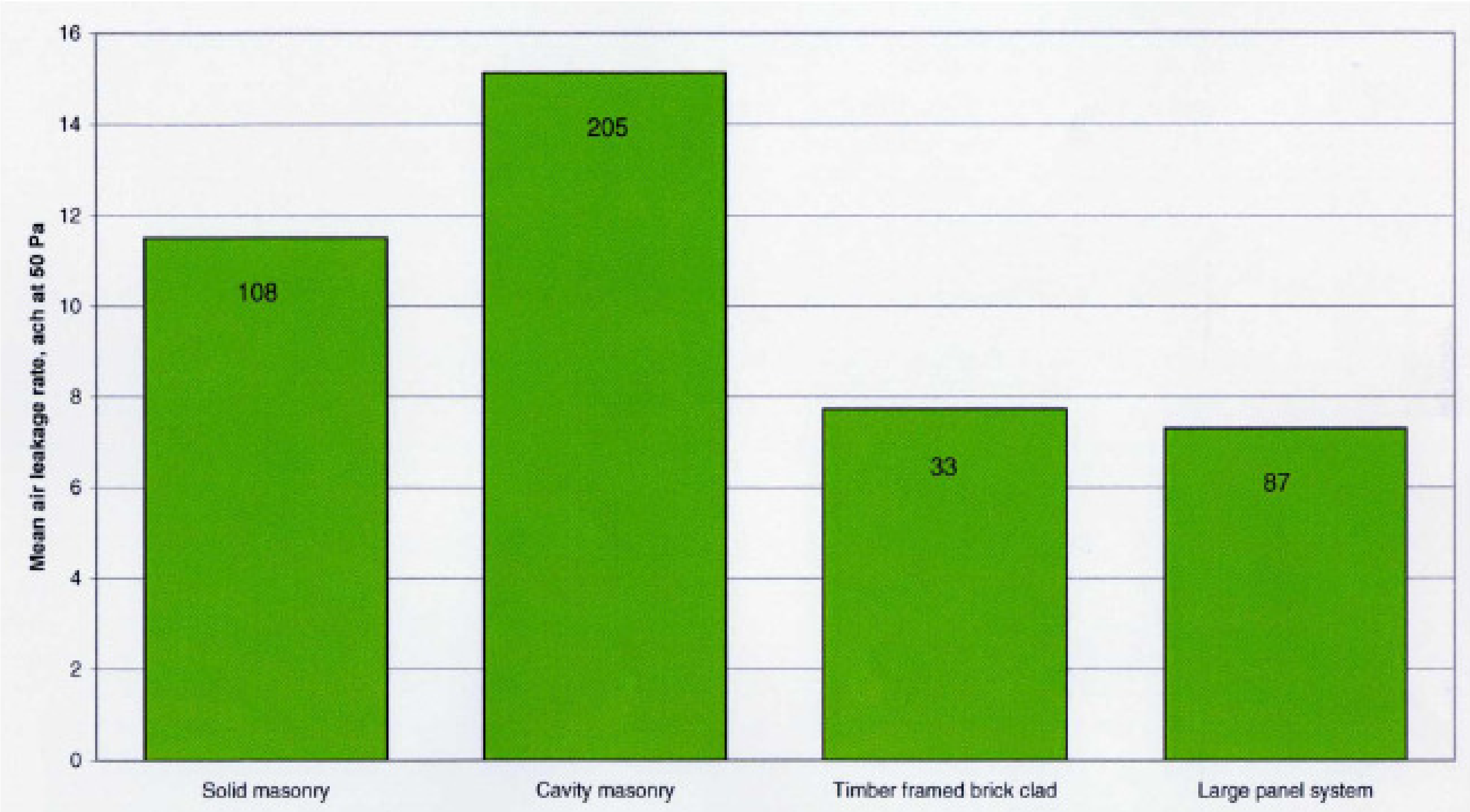
Air permeability based on construction type

IP 1/00 BRE



Summary of IP1/00 report

– Mean air permeability 11.48 $m^3/(h.m^2)$ @ 50Pa (equivalent to 13.1 ac/h @ 50 Pa)
– For dwellings without background ventilation a value of 10 – 15 ac/h @ 50 Pa is desirable
– For dwellings with trickle vents a value of 10 – 15 ac/h @ 50 Pa is desirable
– Age of dwelling did not affect permeability (some older dwellings were more airtight than newer dwellings)

– Wall type did affect permeability (permeability increased from large panel systems in flats were more air tight, followed by timberframe brick clad, then solid masonry and lastly cavity masonry)
– Ground floor construction affected permeability (solid concrete slab more air tight than suspended timber floor)
– Drying out:
  - New build timberframe leakage rates increased by 10% after 12 months
  - New build masonry leakage rates increased by 17% after 12 months

14.6 Improving Air Tightness

- On completion of this module learners will be able to:
  - Discuss how to incorporate the concept of structural air tightness into the life cycle of a project
  - Identify examples of good practice for structural air tightness

When do you start considering structural air tightness?

Air tightness needs to be addressed at design stage and construction stage.

- **Design Stage**
  - Simplify built form
  - Define the line of the air barrier
  - Decide and specify which materials will form the air barrier.
  - Minimise the number of service penetrations through the external wall.
  - Consider how service penetrations will be sealed.
  - Apportion responsibility for sealing critical junctions to specific trades.

- **Construction Stage**
  - Appoint a site “air barrier manager”
  - Brief the whole construction team on the need for and importance of the air barrier.
  - Air barrier management to undertake:
  - Coordination of the formation of the air barrier
  - Site quality assurance
  - Check and sign off all “hidden” air barrier elements before covering up.

<u>Undertake air tightness testing at the earliest possible opportunity.</u>

Construction details to help improve air tightness

Images on the following nine slides are taken from Sustainable Energy Authority of Ireland's (SEAI) publication "Limiting Thermal Bridging and Air Infiltration – Acceptable Construction Details 2008"

Sealing the junction between the joist and the external wall

"Limiting Thermal Bridging and Air Infiltration – Acceptable Construction Details 2008" SEAI

Sealing where pipes enter the roofspace

"Limiting Thermal Bridging and Air Infiltration – Acceptable Construction Details 2008" SEAI

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Bonding an air-tight membrane to the concrete floor slab

"Limiting Thermal Bridging and Air Infiltration – Acceptable Construction Details 2008" SEAI

"Limiting Thermal Bridging and Air Infiltration – Acceptable Construction Details 2008" SEAI

Sealing at intermediate floors: First stage: point up around joists

"Limiting Thermal Bridging and Air Infiltration – Acceptable Construction Details 2008" SEAI

Sealing at intermediate floors: Second stage: tape joists to wall

"Limiting Thermal Bridging and Air Infiltration – Acceptable Construction Details 2008" SEAI

Sealing under way at junction of timber frame wall and external wall ope

"Limiting Thermal Bridging and Air Infiltration – Acceptable Construction Details 2008" SEAI

Sealing around connection to electrical socket outlet

"Limiting Thermal Bridging and Air Infiltration – Acceptable Construction Details 2008" SEAI

Sealing around frame of access hatch to attic

"Limiting Thermal Bridging and Air Infiltration – Acceptable Construction Details 2008" SEAI

Summary of Structural Air Tightness

- Air permeability is the parameter used to assess structural air tightness
- Values range from 10 $m^3/(h.m^2)$ @ 50 Pa (good practice) to 3 $m^3/(h.m^2)$ @ 50 Pa (best practice)
- PassivHaus standard is even stricter at 0.6 ACH @ 50 Pa
- To achieve good air tightness build quality needs to be addressed at design stage and construction stage

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- Suggested Reading
  - GPG 268 “Energy efficient ventilation in dwellings – a guide for specifiers”, Energy Savings Trust, ww.est.org.uk/bestpractice
  - Limiting Thermal Bridging and Air Infiltration Acceptable Construction Details”, Sustainable Authority of Ireland, www.seai.ie
  - IP1/00 “Air Tightness in UK Dwellings”, BRE Environmental Engineering Centre, www.bre.co.uk
  - AVASH project, www.brighton.ac.uk/avash/
  - Air Tightness Testing of New Dwellings, BSRIA, www.bsria.co.uk
  - See also Module 12.2