# **Building and Testing Airtight Buildings** IMPACT AND LESSONS LEARNED

APEGBC Airtightness in Buildings Seminar June 21, 2017 Lorne Ricketts | M.A.Sc., P.Eng.



# Outline

- $\rightarrow$  Air Barrier Design
- → House versus High-rise
- → Where We're At Measured Performance
- $\rightarrow$  Impact of Testing
- → Codes & Standards

# Air Barrier Design

#### **#1: Continuity**

- → Must be continuous between all enclosure elements, from above to below grade, walls to windows and doors, roof & everything in between
- $\rightarrow$  Relies on more than one material
- → Compatibility of adjoining materials critical for long term sealing





#### **#2: Air Impermeability**

- → Materials must be resistant to flow or air at pressures experienced in the building
- → Air barrier materials of less than 0.02 L/s·m² (0.004 cfm/ft²) @ 75 Pa
- → Air barrier systems of less than 0.2 L/s·m² (0.04 cfm/ft²) @ 75 Pa
- → Most materials & systems easily meet requirements



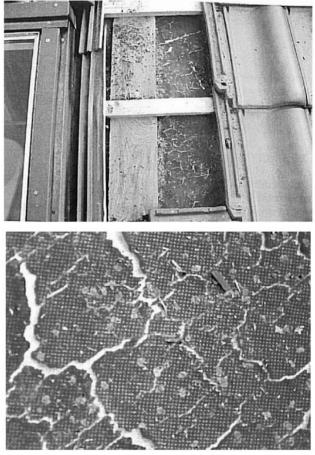
Most CMU is not an airtight material by code definition unless coated

- $\rightarrow$  Peanut Butter (brand unknown) 20 mils
  - $\rightarrow$  0.0041 cfm/ft<sup>2</sup> @ 75 Pa More than twice as tight as Tyvek!



#### #3: Durability

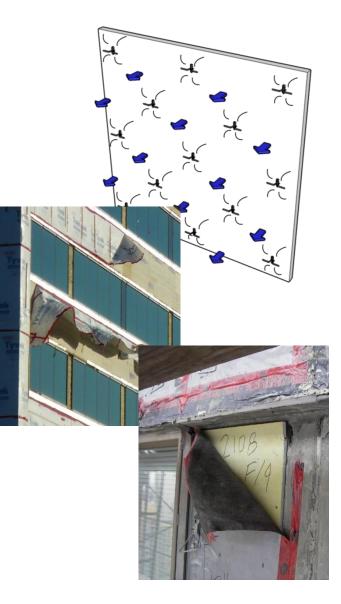
- → Air Barrier System must be durable enough to last as long as the enclosure assembly that it is installed into
- → Must be able to take stresses due to assembly/material movement
- → Must not degrade due to high or low temperatures, moisture, chemicals, contaminants, UV (if exposed) during construction & in-service



Untried air barrier membrane product from Europe – failed due to heat aging effects in roof assembly

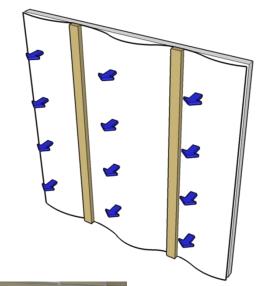
#### #4: Strength

- → Air barrier systems must be designed for the structural wind & resulting building pressure loads
- → Joints and fasteners often critical, especially for flexible unadhered membrane systems
- → Adhesion of tapes/sealants critical to performance & are often the strength limiting component



### **#5: Stiffness**

- → Air barrier system must be stiff enough so that deformations do not change the air-permeance or lead to damage
- → One-side supported sheet membranes create challenges



### Many Air Barrier Systems Available



Loose Sheet Applied Sealed Gypsum Sheathing Liquid Applied Mass Walls Membrane - Taped Joints - Sealant Filler at Joints Sealants/Membranes (concrete) & Strapping BUT, IT'S THE DETAILS THAT MATTER



Self-Adhered vapor permeable membrane



Self-Adhered vapor impermeable membrane

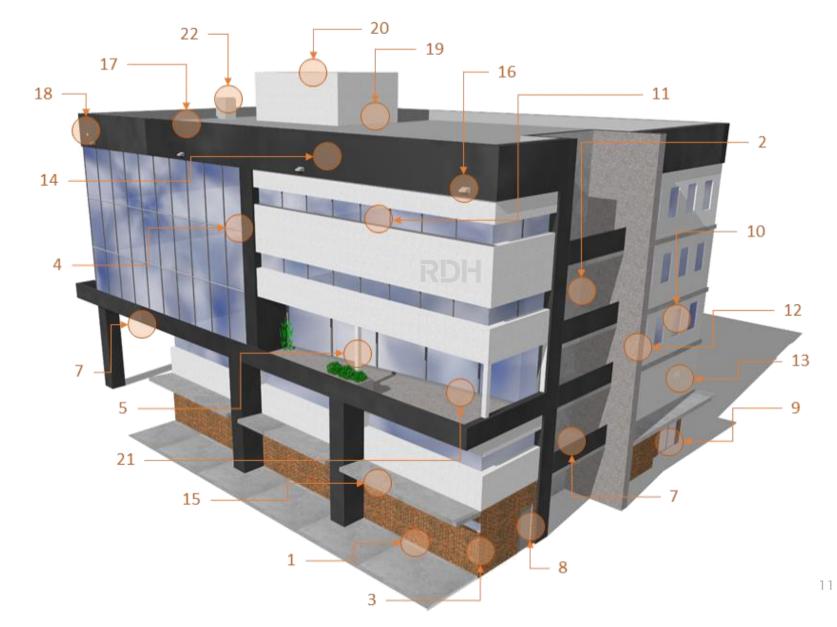


Sprayfoam



*Curtainwall, window-wall* & glazing systems

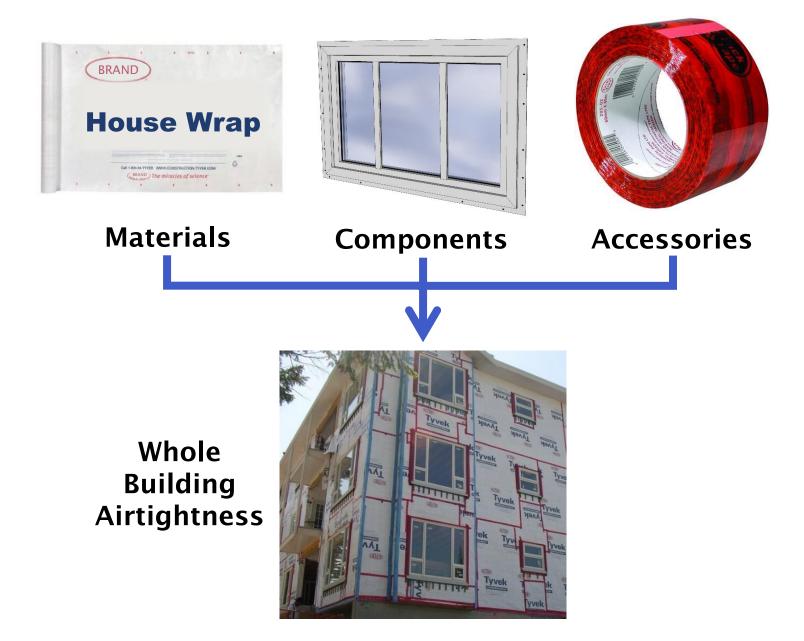
## **Only As Strong As Weakest Detail**



# **Only As Strong As Weakest Detail**







# **Context - Other Jurisdictions**

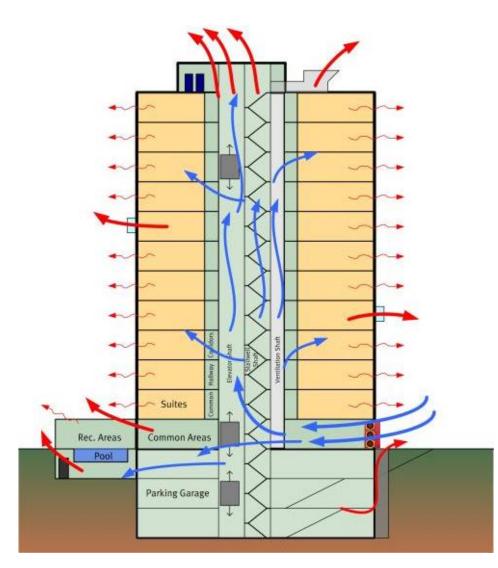
- → Washington State & Seattle, ABAA Target, GSA, IBC/IECC Option < 2.0 L/(s·m<sup>2</sup>) [0.40 cfm/ft<sup>2</sup>] @ 75 Pa
- → US Army Corps of Engineers & IGCC < 1.26 L/(s·m²) [0.25 cfm/ft²] at 75 Pa
- → Passive House 0.6 ACH50
  - $(\sim 0.60 \text{ L}/(\text{s} \cdot \text{m}^2) [0.12 \text{ cfm/ft}^2] \text{ at } 75 \text{ Pa})$
- → LEED, 6-sided apartment test (~1.25 L/(s·m<sup>2</sup>) [0.25 cfm/ft<sup>2</sup>] at 50 Pa)
- → UK (AATMA) Large Buildings ~0.70 to 1.75 L/(s·m²) at 75 Pa [~0.14 to 0.34 cfm/ft² at 75 Pa]



# Airtightness Testing: House versus High-rise

# **Test Methods and Procedures**

- → Most common airtightness test methods are based on similar fundamental principles
- → Fans are used to create a pressure difference across the building enclosure
- → Airflow rate through the fan at specific pressure difference(s) recorded



# **Standards & Qualifications**

Many Standards Exist

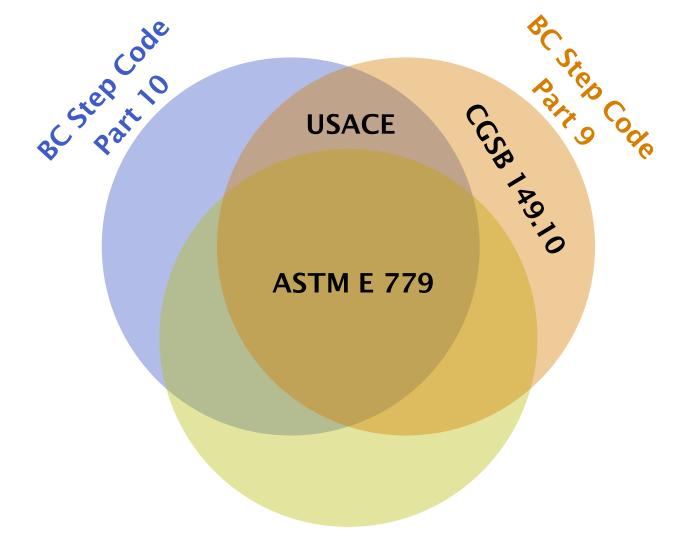
- → CGSB 149.10 & 149.15
- → ASTM E 779 & ASTM E 1827 (blower door)
- $\rightarrow$  US Army Corps of Engineers
- $\rightarrow$  Air Barrier Association of America (ABAA)
- $\rightarrow$  National Environmental Balancing Bureau (NEBB)
- → Airtightness Testing and Measurements Association (ATTMA) in the UK

Not Many Qualification Programs Exist

 $\rightarrow$  NEBB Building Enclosure Testing Certified Professional



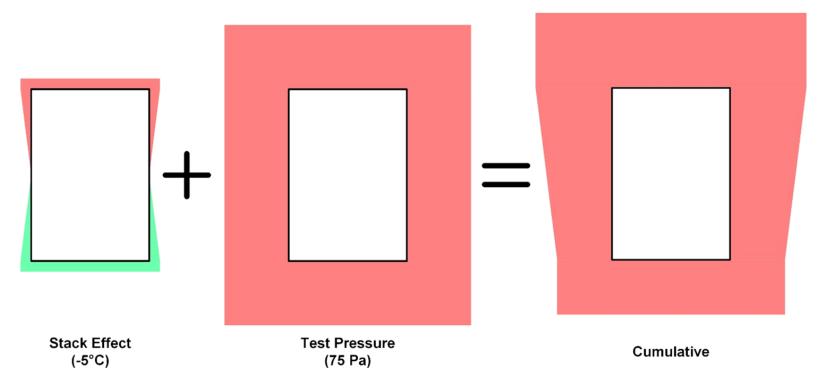
# **Airtightness Testing Standards**



**CoV Rezoning Policy** 

# **Test Methods and Procedures**

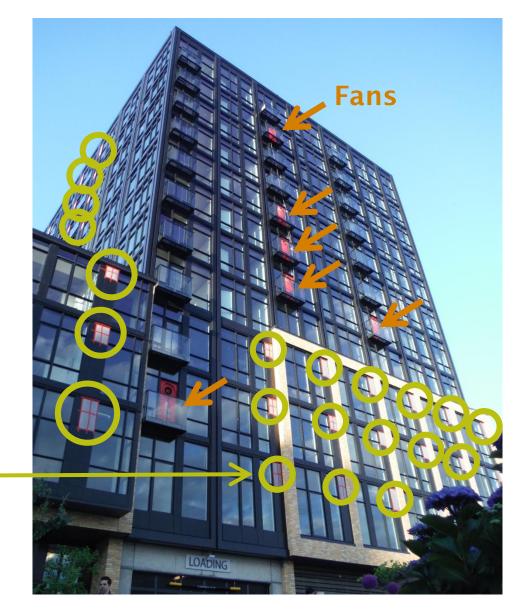
- → Fan induced pressures must exceed building pressures to mitigate noise in data and potential for error
- $\rightarrow$  More difficult for large buildings than for houses



### **Test Methods and Procedures**

→ More than just a bigger house test

#### How do you get here to seal these?



# Lots of Gear...

RDH

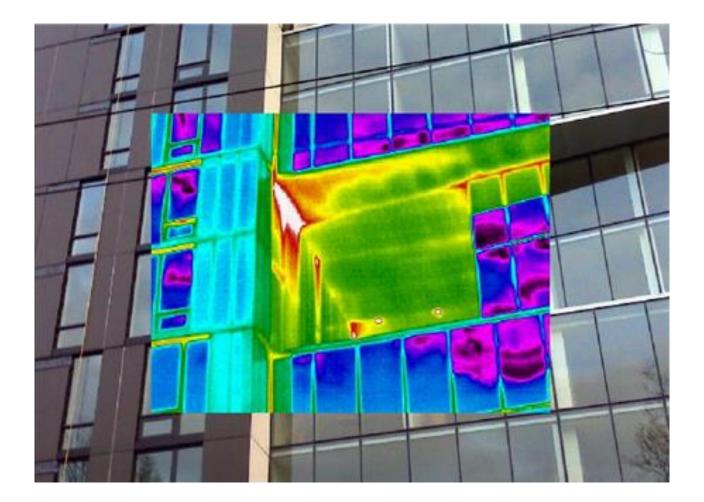
C4900

# **Test Methods and Procedures**

- → Testing may be difficult for buildings which are:
  - $\rightarrow$  Large
  - $\rightarrow$  Tall
  - $\rightarrow$  Air-leaky and/or
  - $\rightarrow$  Compartmentalized
- → It may be more feasible to test smaller sections
  - → Floor-by-Floor
  - $\rightarrow$  Suite-by-Suite



# Finding the Leaks - Infrared Thermography



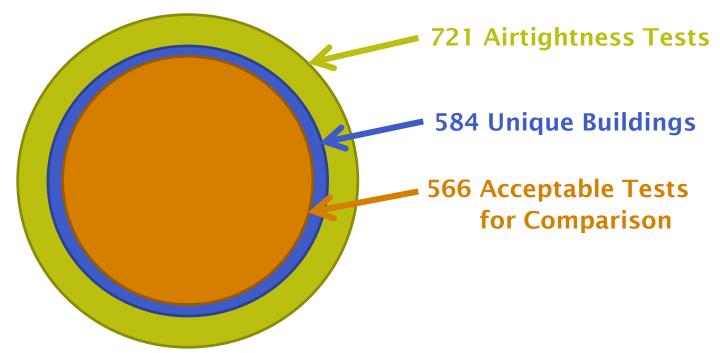
# **Finding the Leaks – Smoke Tracer**



# **Measured Performance**

# **Where We're At – The Numbers**

- → Airtightness testing data was compiled in a database from the following sources:
  - $\rightarrow$  Published literature
  - $\rightarrow$  Industry members
  - $\rightarrow$  Unpublished data provided by the project team



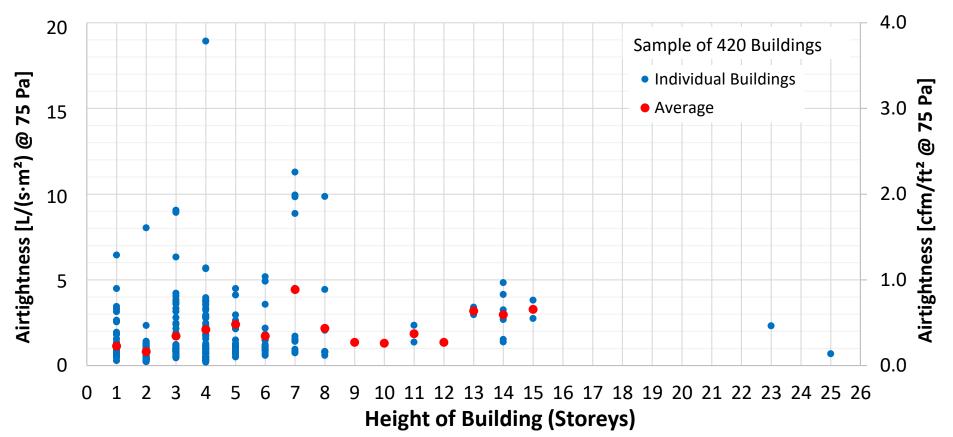
# Where We're At – The Numbers

#### 4.0 Sample of 179 Buildings Airtightness [L/(s·m²) @ 75 Pa] Airtightness [cfm/ft² @ 75 Pa] 3.0 2.0 1.0 0.0

#### **Airtightness vs Year of Construction**

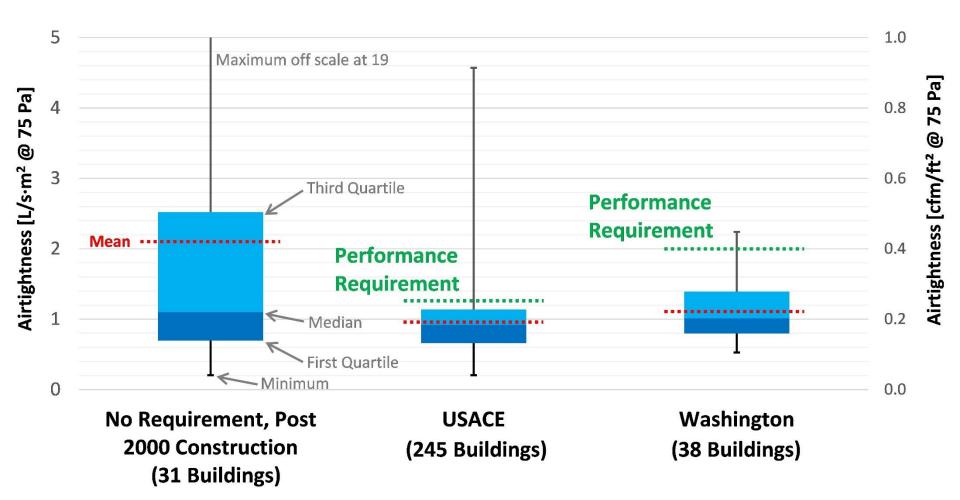
**Construction of Building [year]** 

# Where We're At – The Numbers

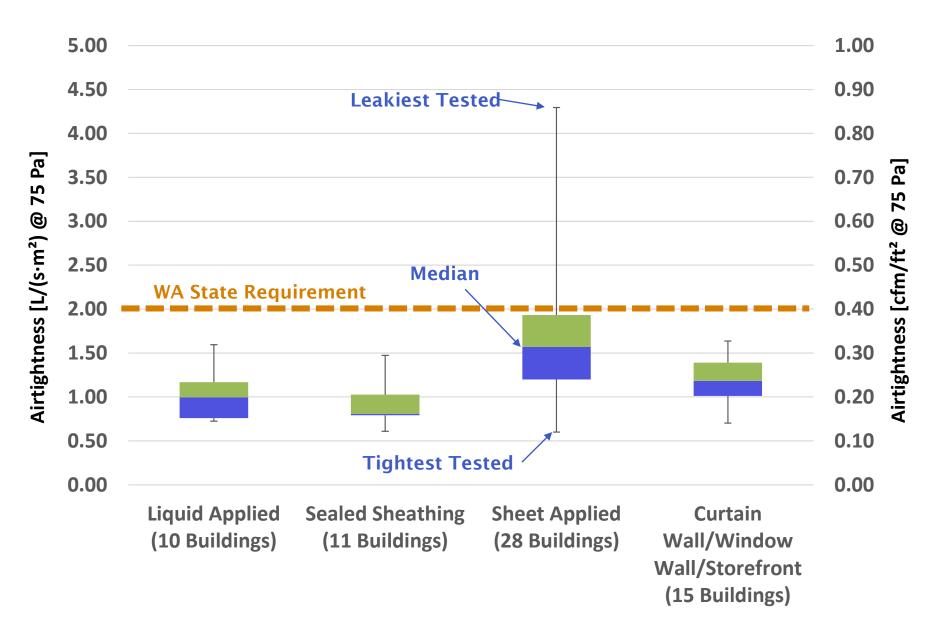


#### **Airtightness vs Height of Building**

# **Impact of Requirements**

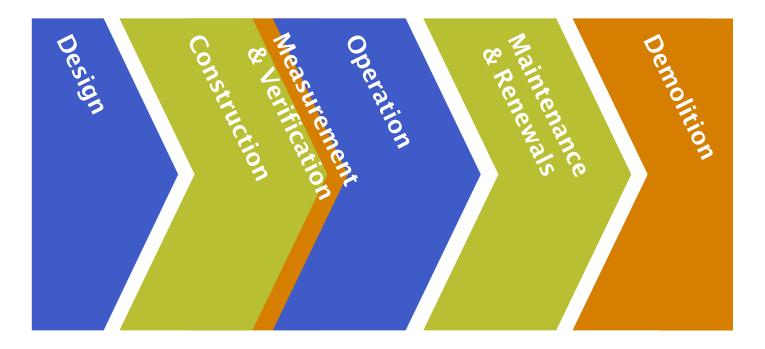


## **Performance of Air Barrier Systems**



# **Impact of Testing**

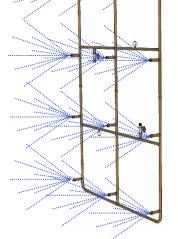
## The Life of a Building



# **Other On-Site M&V Measures**



Commissioning of Fire Safety Systems



Water Penetration Testing of Windows



Balancing of HVAC Systems

# The Life of a Building



Upstream Effects

**Material Selection** 

Assembly Design

**Quality Control** 

# **Changes in Air Barrier System Selection**

→ Seeing shifts from Mechanically Attached to Self-Adhesive & Liquid Applied membranes



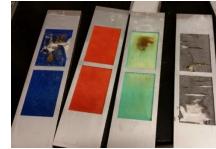
# **New AB/WRB Materials**

→ Many new self-adhered and liquid applied vapour permeable sheathing membranes available on the market









#### **Lessons Learned So Far...**







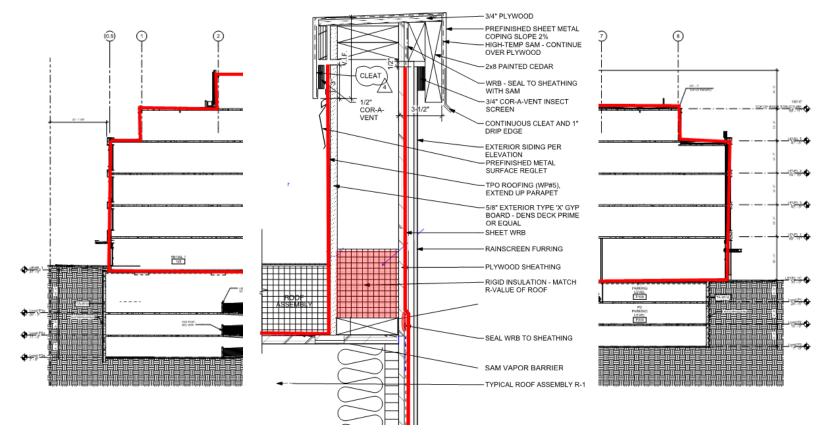






#### **Changes in Design**

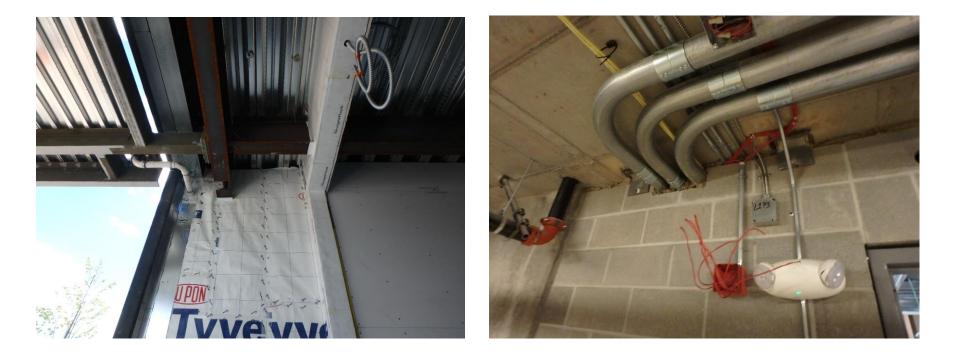
→ Clear identification of air barrier on all drawings both at whole building and detail level



#### **Changes in Design**

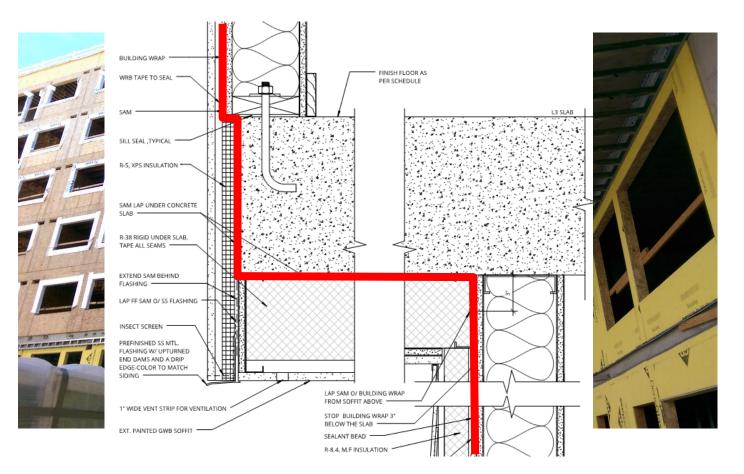
 $\rightarrow$  It's not the details you have, it's the details you don't have

- $\rightarrow$  Fluted decks are often a challenge
- $\rightarrow$  Don't forget interior smoke seals that are part of air barrier



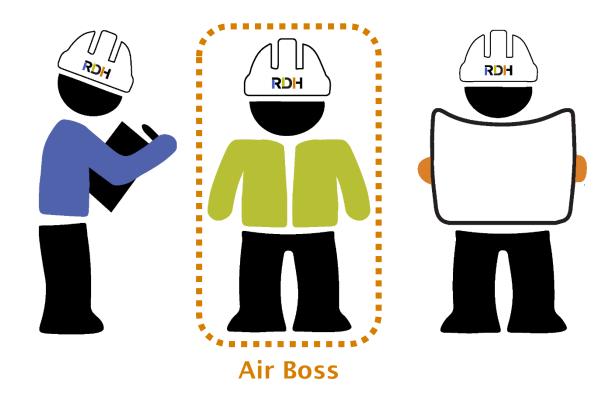
#### **Changes in Construction Practice**

→ Sequencing when different trades comes together is a significant consideration for achieving airtightness



### **Changes in Quality Control**

- → Noticeable improvements as soon as somebody cares specific people designated to look at air barrier
- $\rightarrow$  Coordination between all team members essential



### The Life of a Building





**Material Selection** 

Assembly Design

**Quality Control** 

#### The Life of a Building



#### **Downstream Effects**

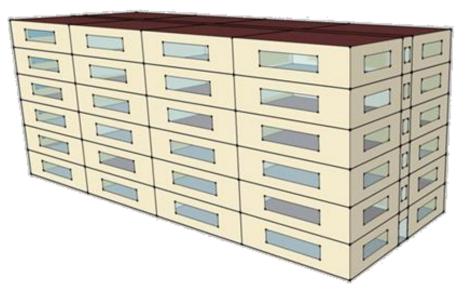
Energy Consumption Indoor Air Quality Acoustics Durability

#### Impact on Energy Consumption – Case Study

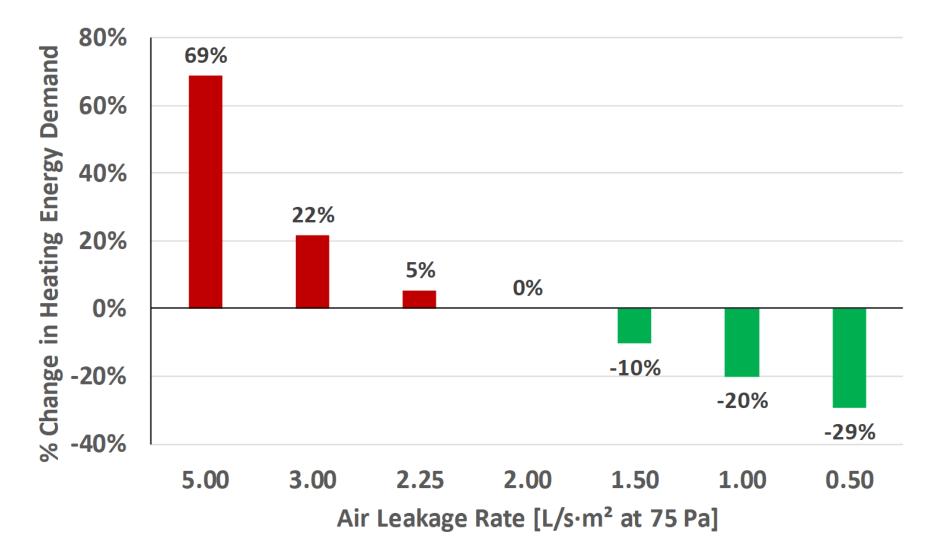
 $\rightarrow$  6-storey 4,700 m<sup>2</sup> wood-frame multi-unit residential building

 $\rightarrow$  Energy Efficient

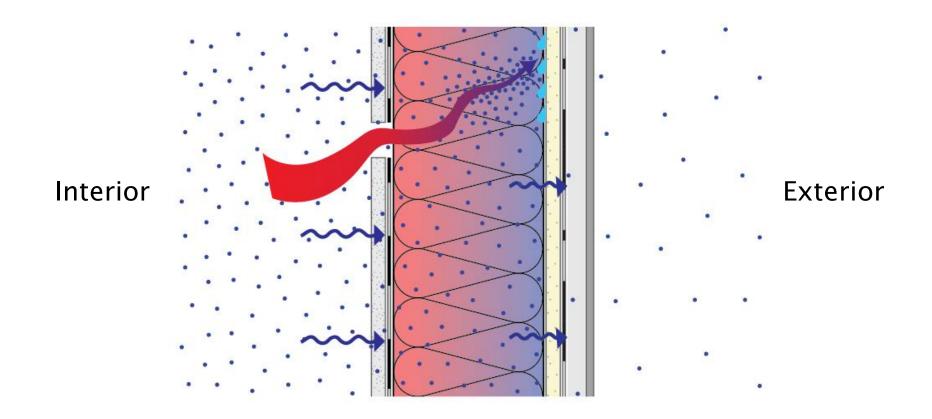
- > R-25 walls and U-0.27 windows
- > 60% efficient HRV
- → Modelled in Vancouver (ASHRAE Climate Zone 4)



#### **Impact on Energy Consumption – Case Study**



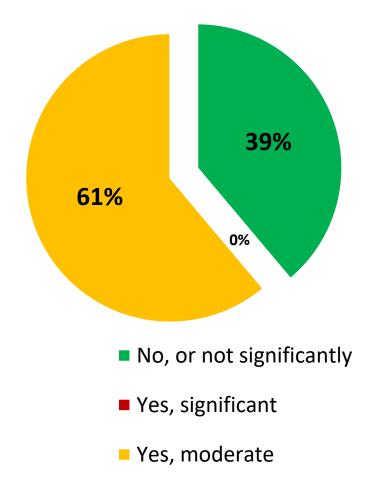
#### Impact on Durability - Air Leakage Condensation



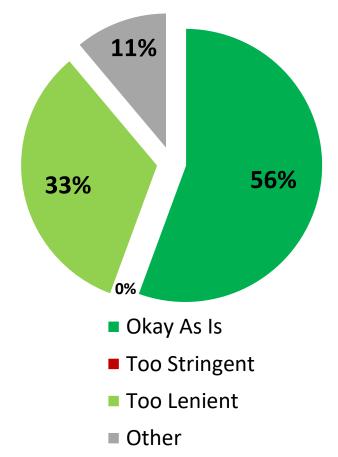


#### **Impact of Requirements**

#### Does airtightness requirement increase cost?

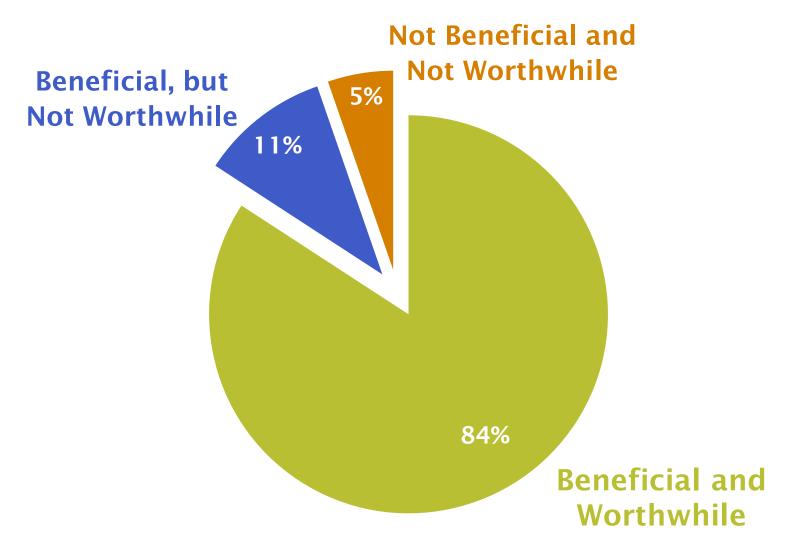


Opinions of the Current Airtightness Target (< 0.40 cfm/ft<sup>2</sup> at 75 Pa) [< 2.0 L/s·m<sup>2</sup> at 75 Pa]



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#### **Impact of Requirements**



# **BC/Vancouver Codes**

### **Context - Other Jurisdictions**

- $\rightarrow$  What's in other codes?
  - → NBC, NECB, ASHRAE 90.1, IBC, and IECC:
    - Something like: The building envelope shall be designed and constructed with a continuous air barrier system.
    - > Some material requirements
    - No testing requirements (though sometimes is an option)



# **Airtightness in BC Codes**

#### → BC Building Code (as of April 7, 2017)

- $\rightarrow$  Part 9 Buildings
  - > Whole building airtightness testing required
  - Performance Requirement
    - Step 1 = None
    - Step 2 =  $3.0 \text{ ACH}_{50}$
    - Step 3 =  $2.5 \text{ ACH}_{50}$
    - Step 4 =  $1.5 \text{ ACH}_{50}$
    - Step 5 =  $1.0 \text{ ACH}_{50}$
  - Except Step 1, measured airtightness result to be reflected in the energy model
- $\rightarrow$  Part 3 Buildings (Part 10)
  - > NECB or ASHRAE 90.1 is still an option, Step Code is new option
  - > Whole building airtightness testing required for all Steps
  - Except Step 1, measured airtightness result to be reflected in the energy model

### **Airtightness in BC Codes**

#### $\rightarrow$ City of Vancouver

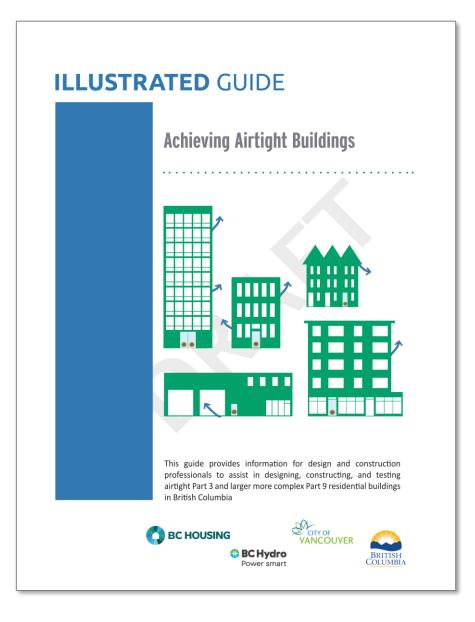
- → Part 9: 1- & 2-family Dwellings
  - > Testing to achieve 3.5 ACH<sub>50</sub>
- $\rightarrow$  Green Buildings Policy for Rezonings (as of May 1, 2017)
  - Testing & reporting required
  - > Target is 2.0 L/s  $\cdot$  m<sup>2</sup> at 75 Pa

#### (3) Airtightness Testing

Whole-building airtightness for each building is to be tested and reported, and all buildings are to be designed and constructed with the intention of meeting an air-leakage target of 2.0 L/s\*m<sup>2</sup> @75 Pa (0.40 cfm/ft<sup>2</sup> @ 0.3"w.c.), or sealed according to good engineering practice.

Buildings that fail to achieve the airtightness target must find and seal the sources of air leakage (using techniques such as visual inspection, smoke testing, and/or thermal imaging), and then re-test the building. If the building is still unable to meet the target, a lessons learned report must be provided for public use that includes the findings of a visual air barrier inspection, any air leaks found and sealed, likely remaining sources of air leakage and why they could not be readily sealed, and recommendations for future buildings to achieve the target.

## **Guide to Achieving Airtight Buildings**



#### **Guide to Achieving Airtight Buildings**

#### CONSTRUCTION CHECKLIST

#### ALLE CIVILIE CONST



CONSTRUCTION CHECKLIST		
Date: Construction Team:		
Project II: Building Address:		
Building:	IESTING CHECKLIG	
Dina. II	TESTING CHECKLIST	
re-Construction Meeting Meet with design team, contractor, and affected sub-trades to discuss air barrier strategy and the team of the team of individual responsible for air barrier completeness		
Meet with design team, contractor, and affected sub-traces to uncostere     Meet with design team, contractor, and affected sub-traces to uncostere     Meet with design team, contractor, and affected sub-traces to uncostere     Meet with design team, contractors     Meet with design team, contractors		
I Identify the site Air Boss or individual responsive to an arresponsive to an arrespons	Date:TESTING CHECKLIST	
Ensure adequate training to the air bar	Date: TESTING CHECKLIST	
Ensure adequate variance for the second sec	Project #	
Make clear everyone's repossibility to report the second sec	Building: Lesting Team:	
	Bullet 1	
Mock-ups Prepare mock-up(s) demonstrating the air barrier details. Prepare mock-up(s) demonstrating to verify air barrier performance and ide	Building Address:	
Mockups Prepare mock-up(s) demonstrating the air barrier details. Preform qualitative and/or quantitative testing to verify air barrier performance and ide perform qualitative and/or quantitative testing design changes.	Qualitative Testing	
Perform qualitative and/or quantitative besting to very set leakage locations. Document any resulting design changes.	Confirm the terminations, details, and laters	
	Completion Particle     Completion appreciations, details, and interface much ups with mode     Completion appreciations, details, and interface much ups with mode     Completion appreciations of all locations shown to be leaking     Decuments mudifications/additions to original design as response      Pre-tage	
Construction are follower	to original design as required	
Construction Consult product literature prior use of all products to ensure instructions are followe Perform adhesion pull tests at for all combinations of sealants, tapes, membranes, a Perform adhesion pull tests are carefield professionalia as required to establish warranty (if	Pro-test	
	Pre-test waikthrough (2 weeks prior): Creck that all one of the second	
	and all Barrier components	
Involve manufactures (mechanical, electrical, etc.,) are aware of their respectives of t	mon event state provid     order state at a brains components are installed and complete     Prain order state for eventing incompletes are invariant.     Prain order state for eventing incompletes are invariant.	
Perform qualitative (smoke, infrared) testing at critical and replace     Perform qualitative (smoke, infrared) testing at critical and replace     Notify enclosure professional when air barrier details are ready for review	er pressure equalizione del barrier componente	
	Condition to work on/m building is scheduled for test day     Coordination meeting (2 days prior):     Review at two models and the scheduled for test day	
Below-Grade Install air barrier pre-stripping before concrete work as required Install air barrier pre-stripping before above grade framing as required	netrew all temporary seals at inc.	
Install air barrier pre-stripping before concrete work as required Install air barrier pre-stripping before above grade framing as required Install air barrier pre-stripping before above grade portions and sea	Coordinate Ada power supplied for each fair Coordinate Ada power supplied for each fair	
Install air barrier pre-stripping before above grade training as requires Install air barrier pre-stripping before above grade training as requires Install below-grade air barrier including tie-ins to above grade portions and sea		
	Concertance 2004 AC 2004 According and generations     Worky work (who building its be completely supported during text period     Concert keys to all doors to all areas of the building can be considering supported.     Concert keys to all doors to all areas of the building can be considered.	
above Grade	sources so all areas of the building can be accessed	
Above-Grade Install air barrier pre-stripping before framing as required Install air barrier pre-stripping as required at penetrations, details, and inter Install air barrier pre-stripping is required by the stopping as the stopping a		- 8
Install air barrier pre-stripping as required at penetrations, details,     Install above grade air barrier including be-ins to below-grade, roofs, openin     Install above grade air barrier including be-ins to below-grade, roofs, openin	Constraints	- 8
Install above grade an outcome penetrations	India open all interior slows and doors or assign door monitors      Remove at least 1% of ceiling tiles      Tern of WAC works.	
		- 11
funderst is installed		_
Services Minimize penetrations made through the air barrier after it is installed Communicate all air barrier penetrations, details, and interfaces not dire Communicate and air barrier penetrations.		_
Communicate all air barrier penetrations, occurs, and construction documents	Close and seal all work water, including sinks, show to standard	_
construction documents	Then of an ad east versition represent part net standard If plancing traps with water, (including stank, showers, tolets, floor drains, washing machines, etc. Coope and seal al versition states, including stank, showers, tolets, floor drains, washing machines, etc. Coope for alarm of for to test mode (if stroke traps.com, trickle words per test standard) Too of devotess	_
Exterior Components  Ensure all air barrier components are installed prior to installing extent  Ensure all air barrier discherent through exterior finishes into air barrie	Oran areas around fans to provent dirt/debris from being blown around     Most areas around around the stop present dirt/windows/transprany seals     Post-test	
Ensure all air barrier components are installed pror to installed     Ensure all air barrier     Minimize "blind" attachement through exterior finishes into air barrie	during testing for blown open door/value	
	Post-test Post-test	
Notes	Complete limited qualitative tarties in .	
Notes:	Post Gast     Complete Instead outlitative statisticy of initial rest results indicate initiad darget     Complete Instead outlitative statisticy of initial rest results indicate initiad darget     Complete Instead outlitative statistics of initial rest results indicate initiad darget	
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	netotre building to anythat lead freads indicate missed target     complete targing is conditione after test (immore temporary seals, famino mi4/aC, etc.)     Assist in coordination/planning for follow-up testing if needed	
	- moved	
	Notes:	
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6   ILLUSTRATED GUIDE TO ACHIEVING		
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	ILLUSTRATED GUIDE TO ACHIEVING AIRTIGHT BUILDINGS   47	
	GUIDE TO ACHIEVING AIRTIGHT BUILT	
	BUILDINGS   47	

#### **Guide to Achieving Airtight Buildings**

AIRTIGHTNESS T	EST REPORTING FORM	Normalized Air Leakage Rate
Project Address Related Building Permit	Building Name Pass Did Not Pass* "Attach supporting documentation	Submission Date
TESTING ORGANIZATION INF Name:	Email:	TEST BOUNDARY         Whole Building       Partial         Floor Area (m?):

### **Bulletin Airtightness Requirements**

Standard	Buildings Where Testing is Required	Mandatory Target?	Airtightness Performance Target	Referenced Test Standard
ASHRAE 90.1-2016	All (except low-rise residential) for possible compliance path	Yes <sup>1</sup>	2.0 L/s·m² @ 75 Pa	ASTM E779, ASTM E1827
BC Building Code (2017)	Part 9 Residential	Yes (except Step 1)	Varies <sup>2</sup>	CAN/CGSB 149.10, ASTM E779, USACE
	Part 3 buildings	No <sup>3</sup>	Max TEDI/EUI <sup>₄</sup>	ASTM E779, USACE
Vancouver Building By-Law (2014)	Part 9 Residential (1- & 2-family dwellings)	Yes⁵	3.5 ACH₅₀	None
Vancouver Green Building Policy for Rezonings (2017)	Near Zero Emission Buildings (Passive House)	No	0.6 ACH₅₀ (if Passive House)	EN 13829 / ISO 9972
	Low Emission Green Buildings	No	2.0 L/s·m² @ 75 Pa	ASTM E779 or equivalent
EnerGuide 15.1 (2015)	Part 9 Residential	No	None	CAN/CGSB 149.10-M86
Energy Star® Homes 12.6 (2015)	Part 9 Residential Attached	Yes	3 ACH₅₀ or 1.32 L/s·m² @ 50 Pa	CAN/CGSB 149.10-M86
	Part 9 Residential Detached	Yes	2.5 ACH <sub>50</sub> or 0.93 L/s·m² @ 50 Pa	CAN/CGSB 149.10-M86
Energy Star <sup>®</sup> MFHR 1.0 (2015)	Part 3 Residential (Suite)	Yes	1.5 L/s·m² @ 50 Pa <sup>€</sup>	ASTM E779 2010, ASTM E1827
IECC (2012)	Part 3 Commercial <sup>7,8</sup> for possible compliance path	Yes <sup>1</sup>	2.0 L/s·m² @ 75 Pa	ASTM E779 or equivalent
	Part 9 Residential <sup>9</sup>	Yes	3 ACH <sub>50</sub>	None
IGCC (2012)	All buildings	Yes	1.25 L/s·m² at 75 Pa	None

# **Discussion + Questions**

#### FOR FURTHER INFORMATION PLEASE VISIT

- → www.rdh.com
- → www.buildingsciencelabs.com

#### OR CONTACT ME

→ Lorne Ricketts - Iricketts@rdh.com

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