University of Waterloo

Moisture Safe High-R Walls

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RDH Building Science

Highly Insulated walls

- Biggest energy users in *new* Canadian houses
  - Space heating followed by
  - Domestic hot water
- Codes and Consumers demand more
  - Increasing Insulation
  - Increasing Airtightness
- Concerns about moisture risk
  - Any change comes with risk of unknown

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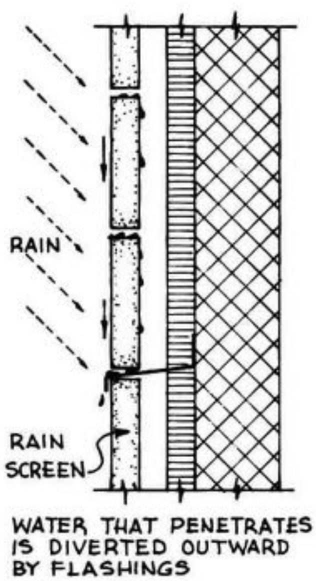
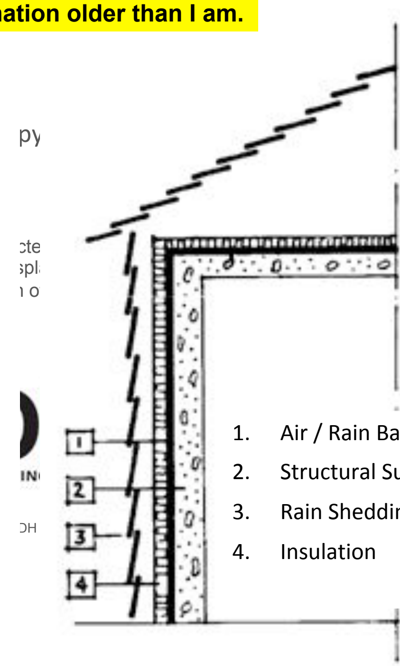
Mom's Rules of Building Science

- Close the window / door / fridge
  - – Airtightness matters
- Wear a hat
  - – Sunshade, rain shelter
- Don't tuck pants into boots
  - – Drainage and shingling
- Wear your jacket, sweater, mittens
  - Insulate on the outside

Design Information older than I am.





1. Air / Rain Barrier
2. Structural Support
3. Rain Shedding
4. Insulation

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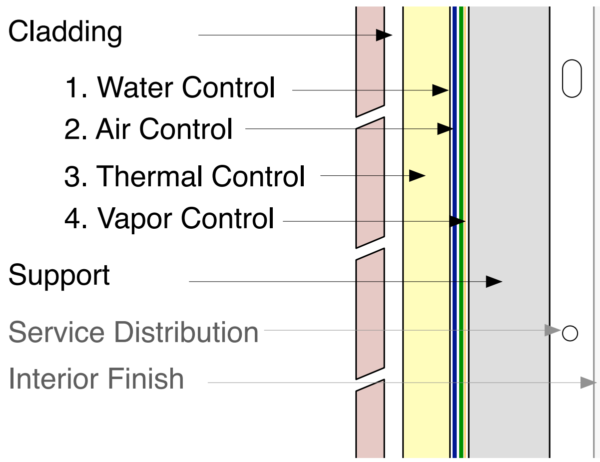
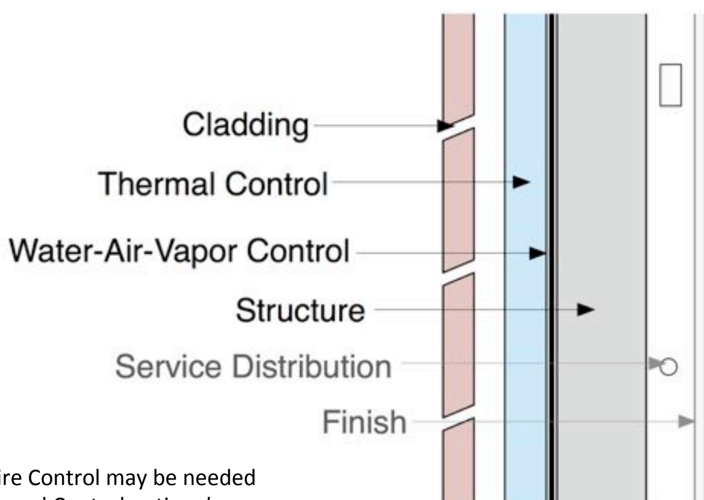
"Perfect Wall"

- Why perfect? Identify layers & Arrangement



Perfect Wall expanded



Fire Control may be needed
Sound Control optional

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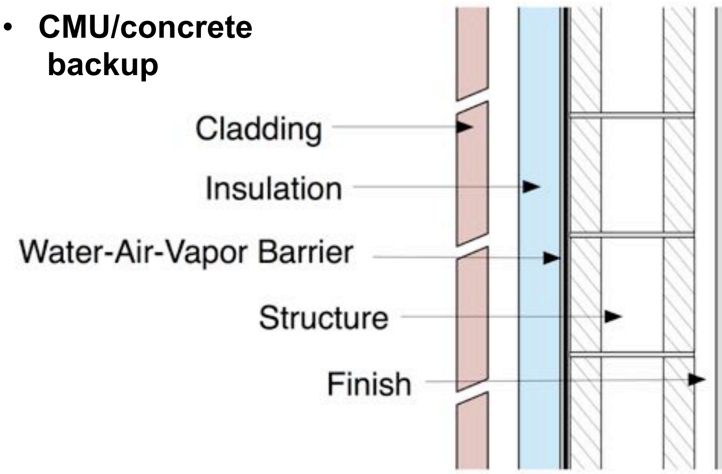
The Perfect Wall

- **CMU/concrete backup**



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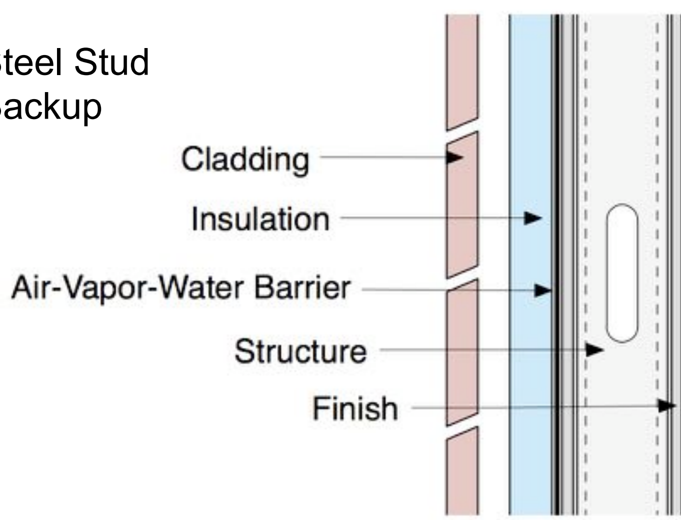
Perfect Wall

- Steel Stud Backup



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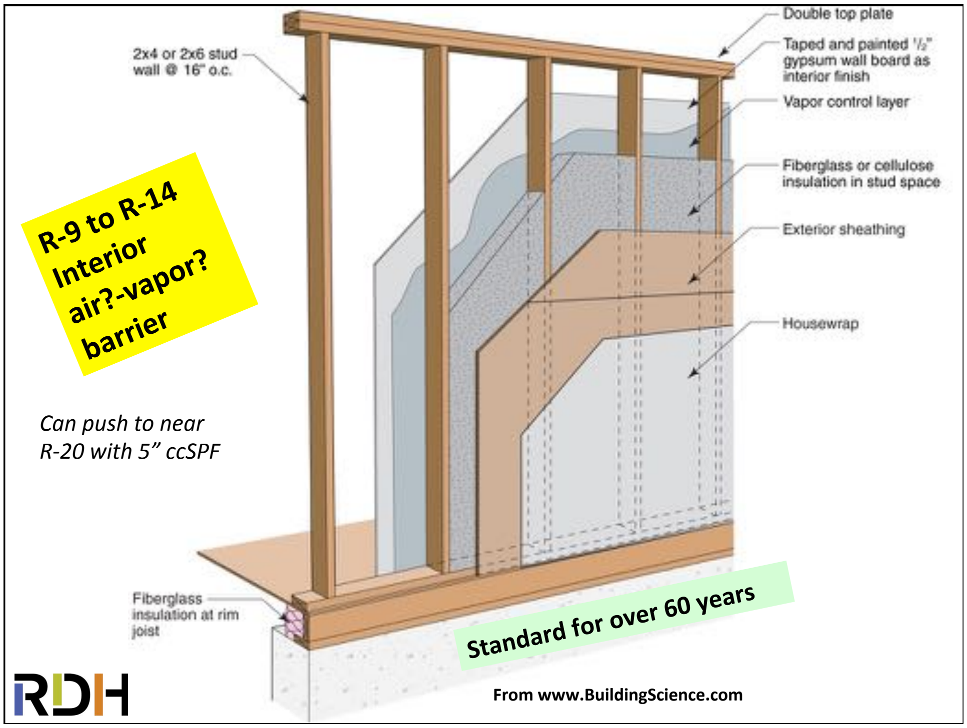
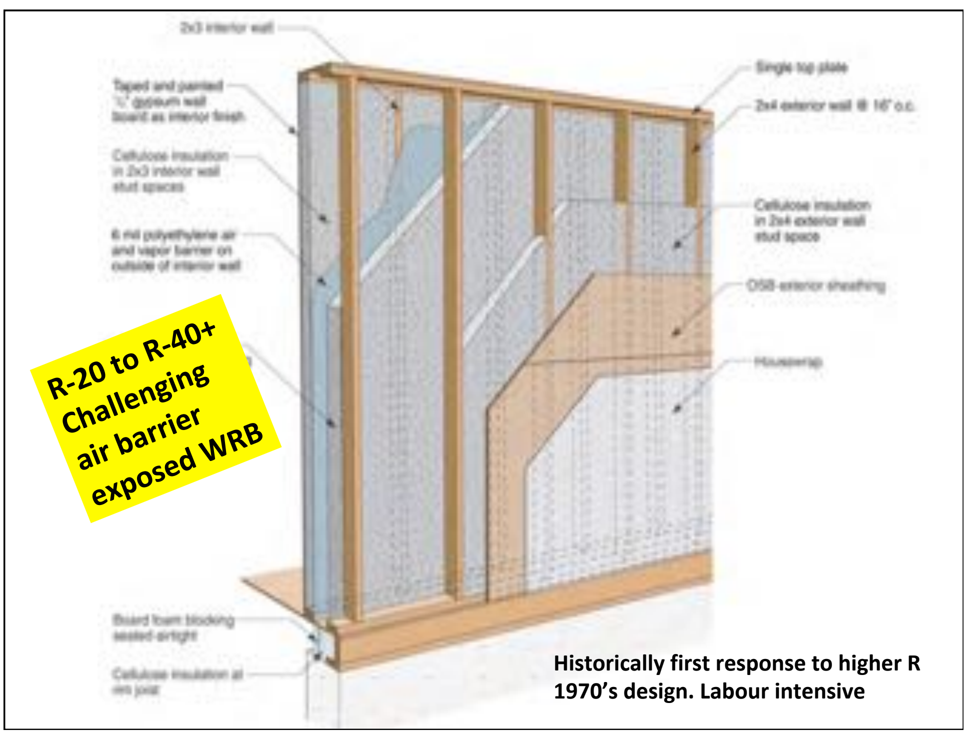
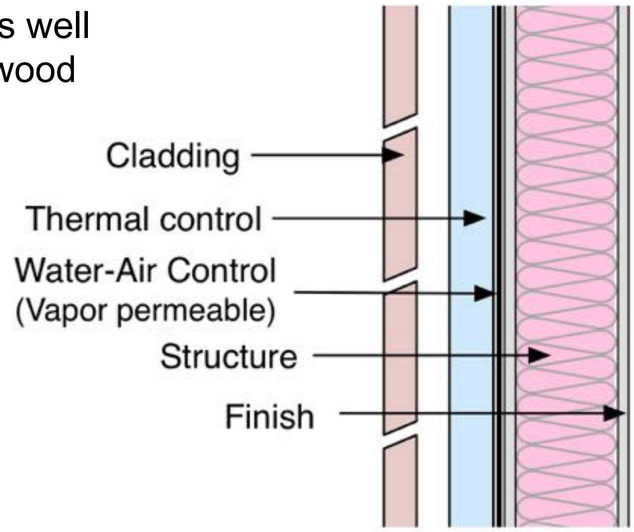
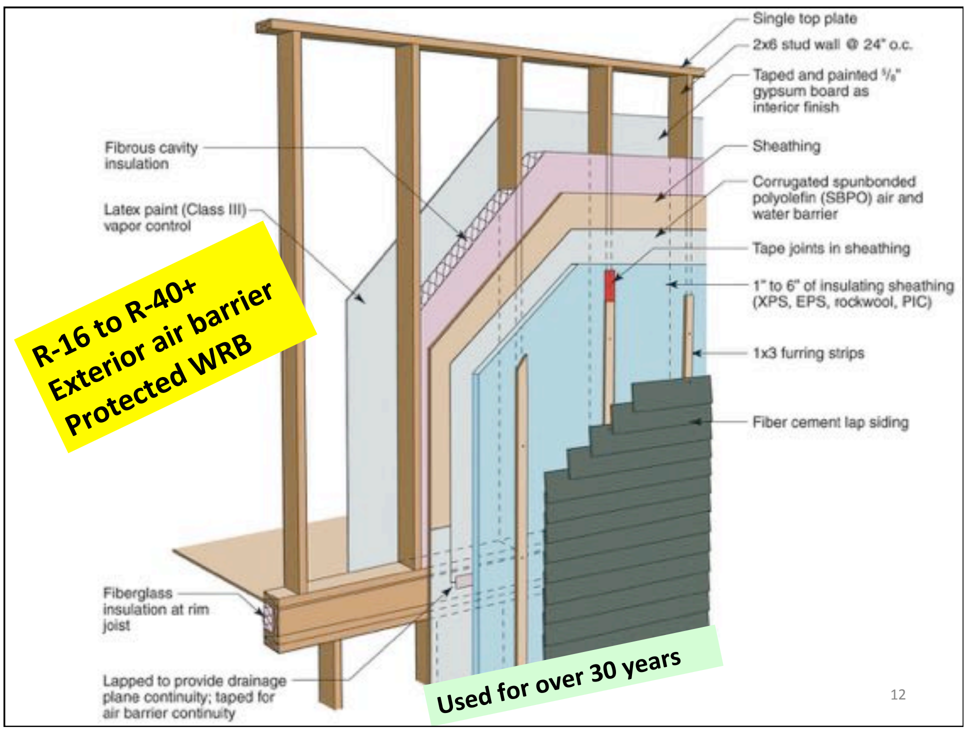

2x4 or 2x6 stud wall @ 16" o.c.
Double top plate
Taped and painted ½" gypsum wall board as interior finish
Vapor control layer
Fiberglass or cellulose insulation in stud space
Exterior sheathing
Housewrap
R-9 to R-14 Interior air?-vapor? barrier
Can push to near R-20 with 5" ccSPF
Fiberglass insulation at rim joist
Standard for over 60 years
From www.BuildingScience.com

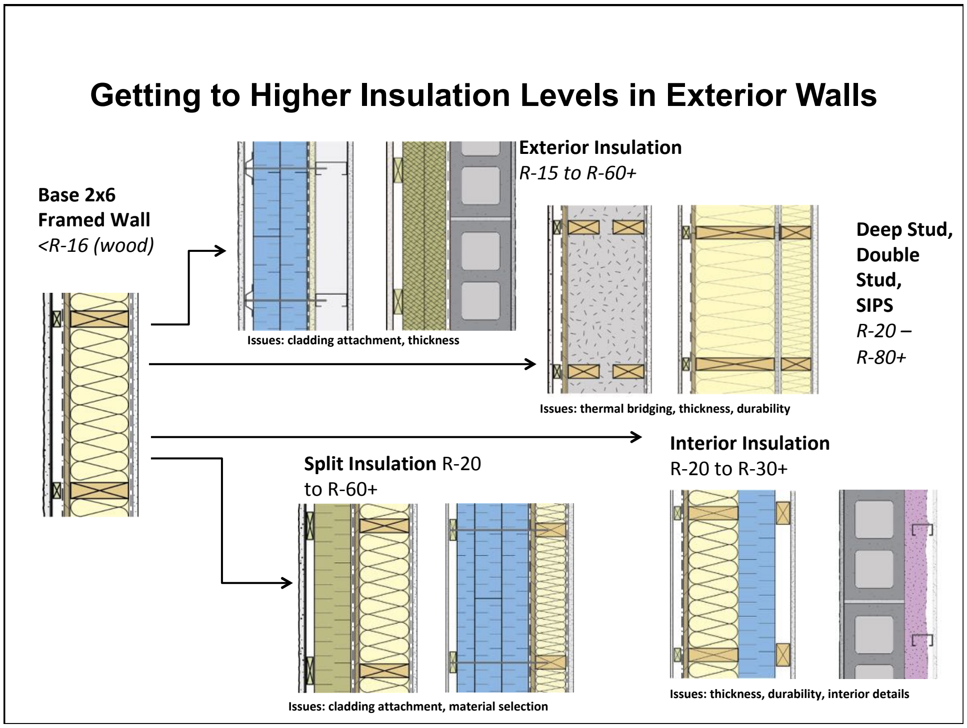

R-20 to R-40+ Challenging air barrier exposed WRB
Historically first response to higher R
1970's design. Labour intensive

The "Perfect" Compromise ☺

- Works well with wood



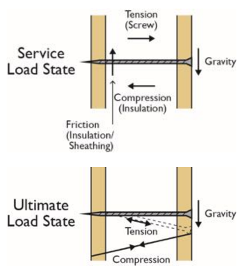



Getting to Higher Insulation Levels in Exterior Walls
Base 2x6 Framed Wall
<R-16 (wood)
Exterior Insulation
R-15 to R-60+
Issues: cladding attachment, thickness
Deep Stud, Double Stud, SIPS
R-20 – R-80+
Issues: thermal bridging, thickness, durability
Interior Insulation
R-20 to R-30+
Split Insulation R-20 to R-60+
Issues: cladding attachment, material selection
Issues: thickness, durability, interior details


Lots of field experience around

Cladding Attachment through Exterior Insulation

Screws through Exterior Insulation & Vertical Strappin



Field Cladding Tests

Moisture and exterior insulation

- Exterior insulation reduces condensation
  - Fewer hours per year
  - Lower quantity
- Exterior insulation slows outward drying
  - Drainage and ventilation enhance drying

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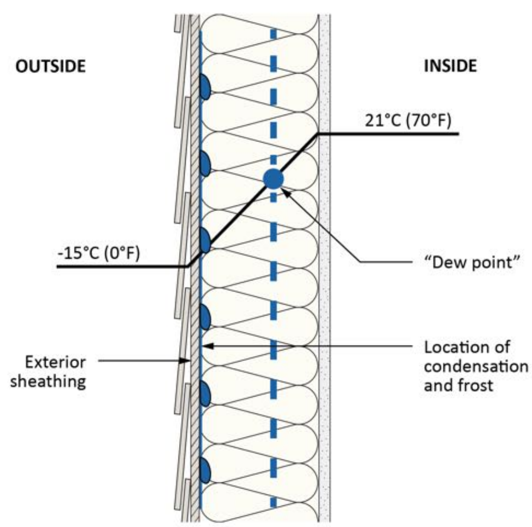
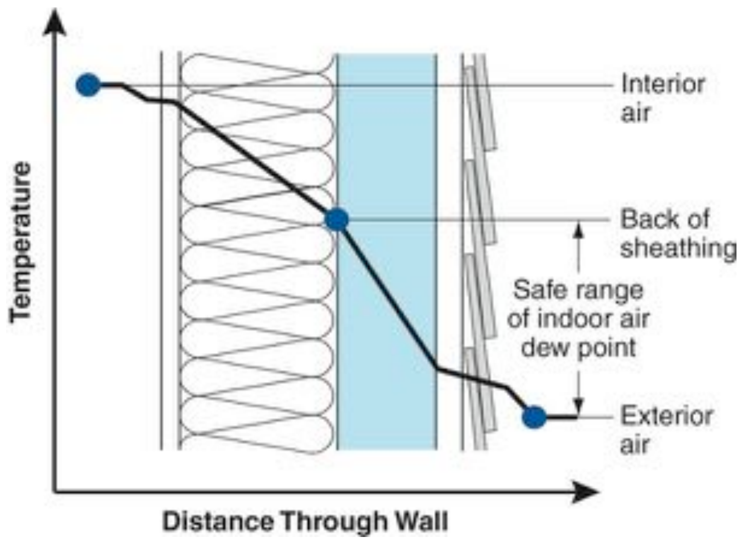
Where does condensation occur?
Diffusion or Air Leakage (Convection)



Exterior Insulation: Condensation



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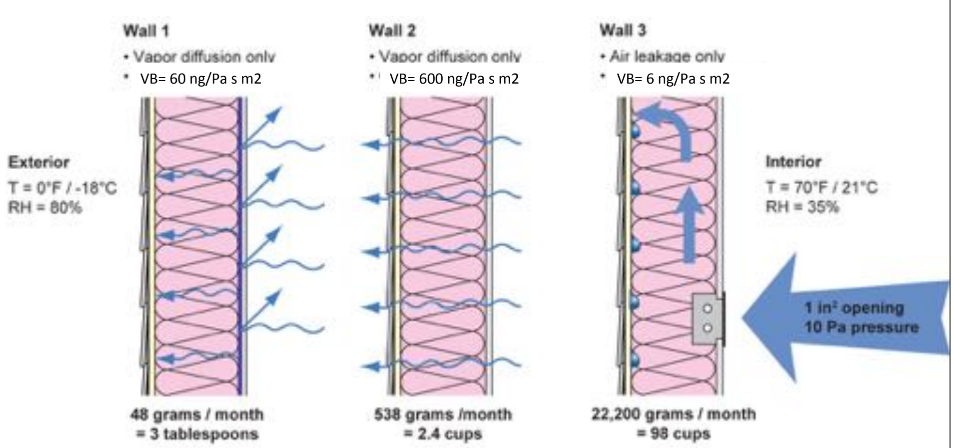
Diffusion vs Air Leakage



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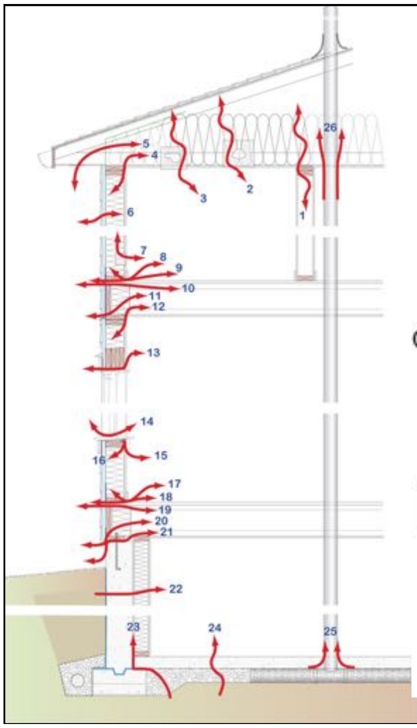
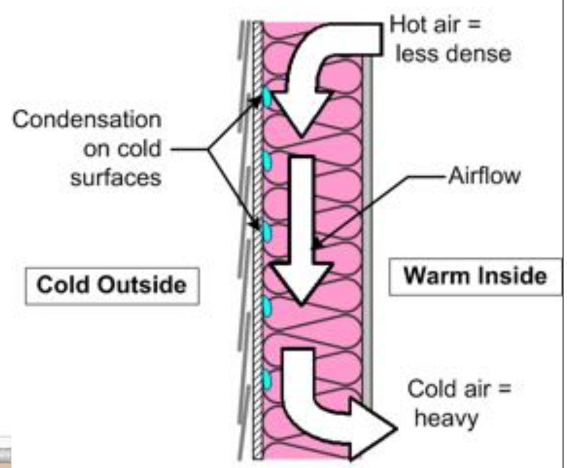
Air leakage pathways





New High-R

- Highly insulated walls can be simple
  - Just add exterior insulation
  - Exterior insulation reduces condensation risk
- Moisture risk goes up *unless* you design for it
  - Add *more* insulation
- Need to think about vapor barriers
  - Balance exterior & interior permeance
- Airtightness still critical

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What is the worst
you can get away with?

ENERGY CODE REQUIREMENTS

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NECB

Representative Manitoba Climate Zones

	HDD	
Winnipeg	5670	
Brandon	5760	ZONE 7A
Portage la Prairie	5600	
Steinbach	5700	
Flin Flon	6440	
Island Lake	6900	ZONE 7B
The Pas	6480	
Thompson	7600	
Churchill	8950	ZONE 8
Lynn Lake	7770	

11 NRC·CNRC

MBC

- Adopted NBCC 9.36
- New Approach- **Effective R-values**
  - All layers matter to thermal resistance
  - big thermal bridges are accounted for
- Review:
  - U-values = 1 / RSI
  - RSI values = 1 / U-values
  - RSI * 5.678 = R-value

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MBC in 2017

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Canadian Code Requirements for Minimum Thermal Resistance of Above Grade Wall Assemblies

	Code/Jurisdiction	Celsius Heating Degree Days for Climate Zones and Typical Locations					
		Zone 4 < 3000	Zone 5 3000 - 3999	Zone 6 4000 - 4999	Zone 7A 5000 - 5999	Zone 7B 6000 - 6999	Zone 8 ≥ 7000
		Vancouver Victoria	Kamloops Kelowna Windsor Hamilton Toronto	Cranbrook Prince Rupert Lethbridge Brampton Ottawa Montreal Fredericton Moncton Saint John Halifax St. John's	Calgary Edmonton Winnipeg Chicoutimi Quebec City Edmundston	Fort McMurray Cold Lake Whitehorse	Yellowknife Nunavut
Effective R-Value	2015 National Building Code 9.36 (No HRV)	15.8 (RSI 2.78)	17.5 (RSI 3.08)	17.5 (RSI 3.08)	17.5 (RSI 3.08)	21.9 (RSI 3.86)	21.9 (RSI 3.86)
	2015 National Building Code 9.36 (with HRV)	15.8 (RSI 2.78)	16.9 (RSI 2.97)	16.9 (RSI 2.97)	16.9 (RSI 2.97)	17.5 (RSI 3.08)	17.5 (RSI 3.08)
	2015 National Energy Code for Buildings	18 (RSI 3.17)	20 (RSI 3.59)	23 (RSI 4.05)	27 (RSI 4.76)	27 (RSI 4.76)	31 (RSI 5.46)
	April 2016 Amended NBC for Manitoba (with HRV. No HRV refer to NBC)	Same as NBC	Same as NBC	Same as NBC	15.9 (RSI 2.80)	15.9 (RSI 2.80)	Same as NBC
	2017 Ontario Building Code SB-12, AFUE ≥ 90%	17.03 - 21.40 (RSI 3.00 - 3.77)			20.32 - 25.32 (RSI 3.58 - 4.46)		

RDI

MBC Part 9

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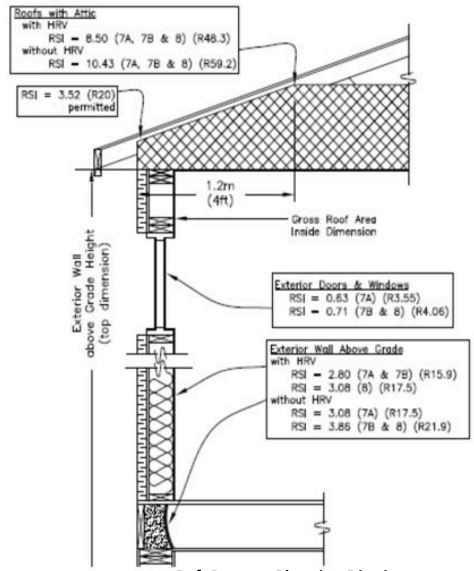


Ref: Portage Planning District

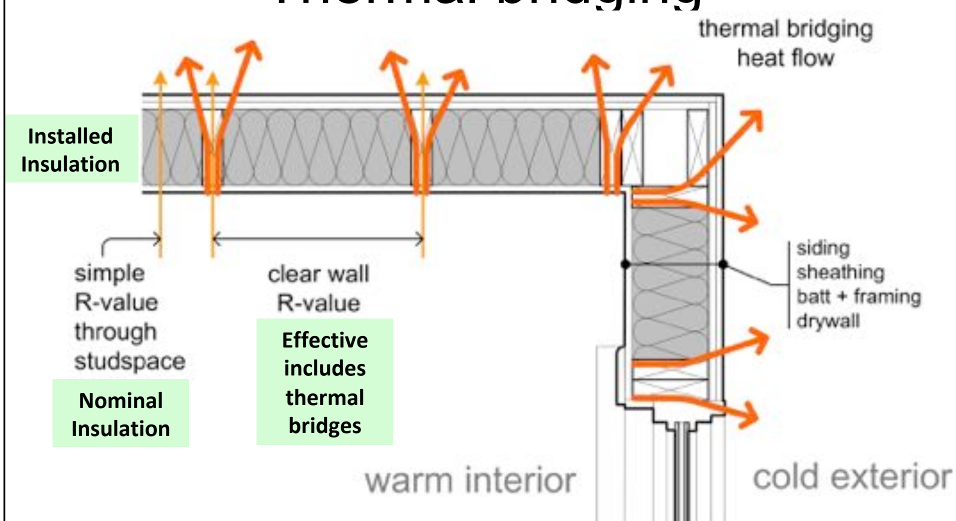
NECB 2011/2015

Heating Degree-Days of Building Location						
	Zone 4 < 3000	**Zone 5** 3000 to 3999	**Zone 6** 4000 4999	**Zone 7A** 5000 to 5999	**Zone 7B** 6000 to 6999	**Zone 8** 7000 to 7999
Maximum Overall Thermal Transmittance (U-value), in W/(m²-K) NECB-2011 Table 3.2.2.2						
Walls	0.315	0.278	0.247	0.21	0.21	0.18
Windows	2.4	2.2	2.2	2.2	2.2	1.6
Roofs	0.227	0.183	0.183	0.162	0.162	0.142
Floors	0.227	0.183	0.183	0.162	0.162	0.142
Approximate **Minimum Overall R-value / RSI-value**						
Walls	18 / 3.2	20 / 3.6	23 / 4.0	27 / 4.8	27 / 4.8	32 / 5.6
Windows	2.4 / 0.42	2.6 / 0.45	2.6 / 0.45	2.6 / 0.45	2.6 / 0.45	3.5 / 0.63
Roofs	25 / 4.4	31 / 5.5	31 / 5.5	35 / 6.2	35 / 6.2	40 / 7.0
Floors	25 / 4.4	31 / 5.5	31 / 5.5	35 / 6.2	35 / 6.2	40 / 7.0

Which R-value?

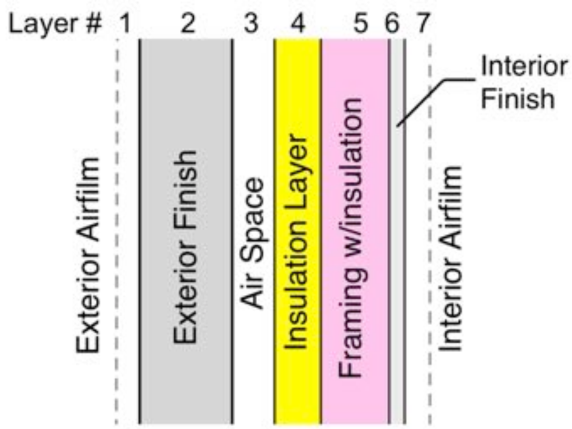
- Installed R-value
- Center-of-Cavity R-value
- Effective R-value
  - Term defined by code
  - includes some thermal bridges
  - ignores some thermal bridges

Thermal bridging



Calculating R-value

- Just add the layer *R-values* for center of cavity



$R_{total} = R_1 + R_2 + R_3 + R_4 + R_5 + R_6 + R_7$

Calculating RSI

- No longer just report what is “in the bag”
- Now: add up all the layers
  - – Interior air film + gypsum (R-1.13)
  - – **Stud** and **batt** *together* (looked at next)
  - – Exterior sheathing, gap (if any) siding
  - – Add any insulating sheathing
- Lot of R-value is still in cavity

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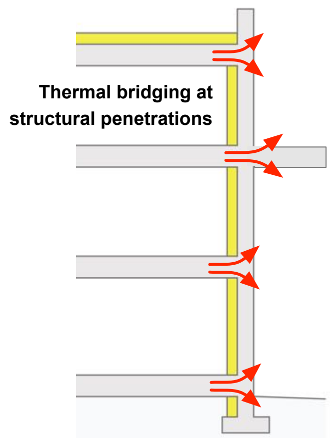
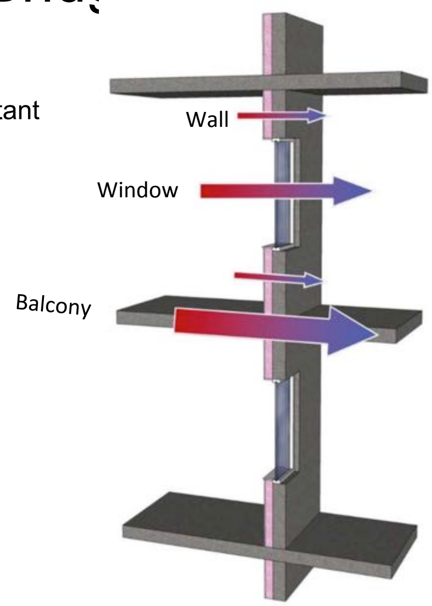
Thermal Bridging

- A local area of the enclosure that has higher heat loss
- Steel studs, floor slabs most important





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Find the thermal bridge


Find the thermal bridge
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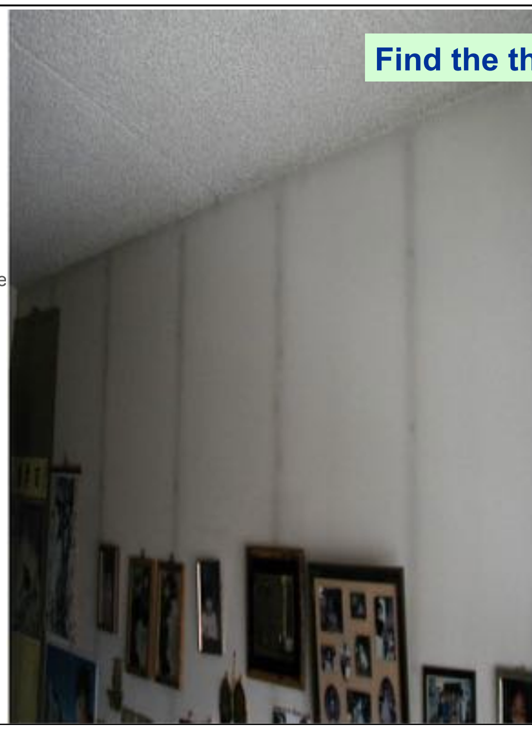
Find the thermal bridge

Find the thermal bridge



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How much is framing

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Table A-9.36.2.4.(1)
Framing and Cavity Percentages for Typical Wood-frame Assemblies[1]

Wood-frame Assemblies	Frame Spacing, mm (in.) o.c.									
	304 (12)		406 (16)		488 (19.2)		610 (24)		1220 (48)	
	% Area		% Area		% Area		% Area		% Area	
	Framing	Cavity	Framing	Cavity	Framing	Cavity	Framing	Cavity	Framing	Cavity
Floors										
lumber joists	–	–	13	87	11.5	88.5	10	90	–	–
I-joists and truss	–	–	9	91	7.5	92.5	6	94	–	–
Roofs/Ceilings										
ceilings with typical trusses	–	–	14	86	12.5	87.5	11	89	–	–
ceilings with raised heel trusses	–	–	10	90	8.5	91.5	7	93	–	–
roofs with lumber rafters and ceilings with lumber joists	–	–	13	87	11.5	88.5	10	90	–	–
roofs with I-joist rafters and ceilings with I-joists	–	–	9	91	7.5	92.5	6	94	–	–
roofs with structural insulated panels (SIPs)	–	–	–	–	–	–	–	–	9	91
Walls										
typical wood-frame	24.5	75.5	23	77	21.5	78.5	20	80	–	–
advanced wood-frame with double top plate[2]	–	–	19	81	17.5	82.5	16	84	–	–
SIPs	–	–	–	–	[illegible]	[illegible]	[illegible]	[illegible]	14	86

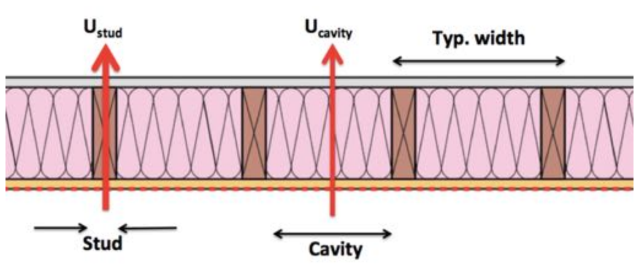
Choose from spacing

Note: SIPS is not zero

Parallel Path Method

First, calculate **thermal transmittance through each of the paths** (eg., wood studs and batt insulation) is calculated.

Then, total heat flow is calculated based on a **weighted average of the areas of each path**



Two Distinct Parallel Heat Flow Paths

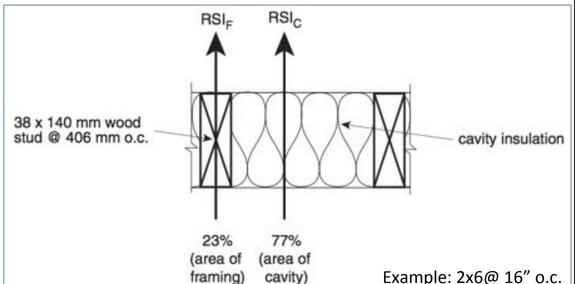
$$U_{AVG} = U_{Stud} \cdot \frac{A_1}{A_1 + A_2} + U_{batt} \cdot \frac{A_2}{A_1 + A_2}$$

Thermal bridging NBCC

- NBCC uniquely uses slight variation on parallel path
- Framing/batt layer is calculated as an equivalent layer (using parallel path) then other layers added

$$RSI_{framing} = \frac{100}{\frac{\%\ \text{area of framing}}{RSI_F} + \frac{\%\ \text{area of cavity}}{RSI_C}}$$

- Slightly less accurate and lower for wood frame walls but quite close



Example: 2x6@ 16" o.c.

Can calculate in R-values or RSI so long as you are consistent

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Parallel Path Example

R-19 batt vs **R-22 batt + R-8 ci**

Path A		**Path B**	
interior film	0.68	interior film	0.68
1/2" GWB	0.56	1/2" GWB	0.56
Batt	19	**2x6**	6.75
7/16" OSB	0.62	7/16" OSB	0.62
Vinyl Siding	0.62	Vinyl Siding	0.62
ext film	0.17	ext film	0.17
Total	**21.7**		**9.4**
Path A %	0.77		0.23
Effective R-value	**16.7**		

Path A		**Path B**	
interior film	0.68	interior film	0.68
1/2" GWB	0.56	1/2" GWB	0.56
Batt	22	**2x6**	6.75
7/16" OSB	0.62	7/16" OSB	0.62
Exterior ci	8		8
Vinyl Siding	0.62	Vinyl Siding	0.62
ext film	0.17	ext film	0.17
Total	**32.7**		**17.4**
Path A %	0.77		0.23
Effective R-value	**27.2**		

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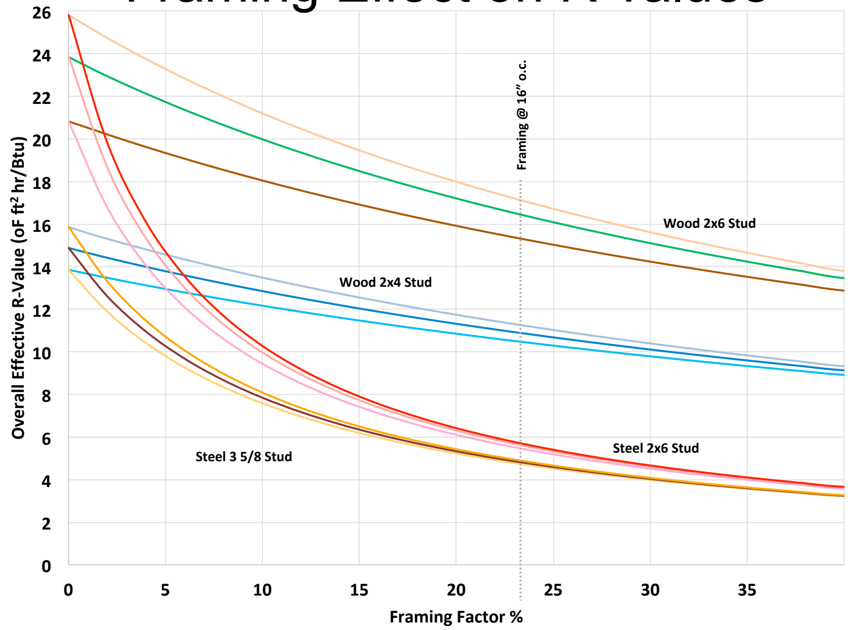
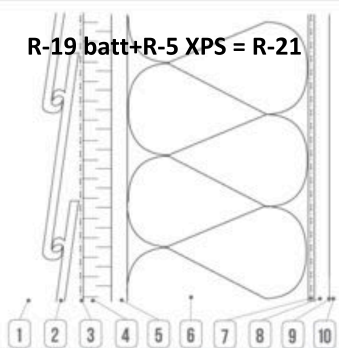
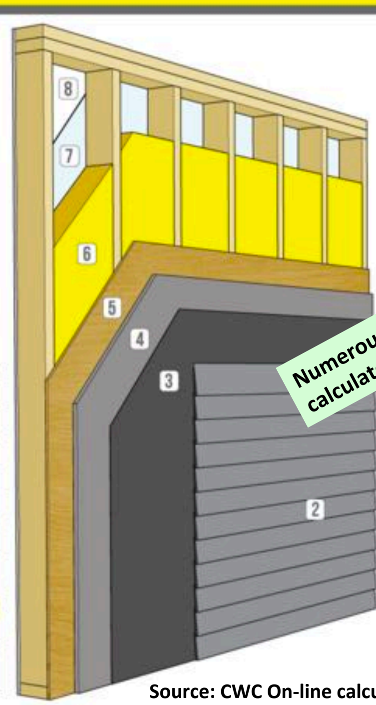
Framing Effect on R-values



R-19 batt+R-5 XPS = R-21



WALL ASSEMBLY COMPONENTS[1]		RSI	R
1	exterior air film	0.03	0.17
2	vinyl siding (no air space)	0.11	0.62
3	asphalt impregnated paper[2]	0.00	0.00
4	1" (25.4mm) extruded polystyrene type 3/4	0.89	5.05
5	7/16" (11.1mm) OSB sheathing	0.11	0.62
6	2x6 framing filled with R19 batt @ 16" o.c.	2.36	13.40
7	polyethylene	0.00	0.00
8	1/2" (12.7mm) gypsum board	0.08	0.45
9	finish: 1 coat latex primer and latex paint	0.00	0.00
10	interior air film	0.12	0.68
Effective RSI / R Value of Entire Assembly		3.70	20.99
Centre of Cavity RSI / R Value		4.68	26.59
Installed Insulation RSI / R Value(nominal)		4.23	24.05
Effective RSI / R Value of Assembly with Advanced Framing (advanced framing as defined by NBC9.36.2.4.(1))		3.83	21.73



Numerous Free on-line calculators available

Source: CWC On-line calculator

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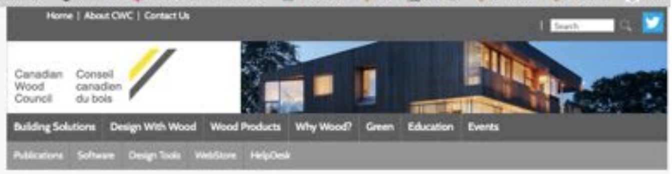
On-line tools to help



CWC. Thermal wall calculator.

Effective Thermal Insulation (Reff) group:

Go to Calculator and Search Now — View Codes Table

< 15.5 | 15.5 - 18.4 | 18.5 - 21.4
21.5 - 24.4 | 24.5 - 27.4 | 27.5 - 30.4
30.5 +

Title	Reff	Rnominal	Framing	Spacing	Cavity Fill	Structural Wood Sheathing	Cladding
F8.S24.I28.O.V	22.1	28	2X8	24 o.c.	R28 batt	7/16 in. OSB	Vinyl
F4.S19.I14.O2X.V	22.1	24.1	2X4	19.2 o.c.	R14 batt	7/16 in. OSB	Vinyl
F8.S24.I28.PW.V	22.1	28	2X8	24 o.c.	R28 batt	1/2 in. Plywood	Vinyl
F6.S19.I19.PW1X.B	22.1	24.05	2X6	19.2 o.c.	R19 batt	1/2 in. Plywood	Brick
F6.S16.I22.PW1X.V	22.1	27.05	2X6	16 o.c.	R22 batt	1/2 in. Plywood	Vinyl
F4.S19.I14.PW2X.V	22.1	24.1	2X4	19.2 o.c.	R14 batt	1/2 in. Plywood	Vinyl
F6.S16.I24.PW1E.B.01	22.1	27.75	2X6	16 o.c.	R24 batt	1/2 in. Plywood	Brick
F6.S16.I19.PW1P.B.01	22.1	24.51	2X6	16 o.c.	R19 batt	1/2 in. Plywood	Brick
F6.S16.I19.O1P.B.01	22.1	24.51	2X6	16 o.c.	R19 batt	7/16 in. OSB	Brick
F6.S16.I24.O1E.B	22.1	27.75	2X6	16 o.c.	R24 batt	7/16 in. OSB	Brick

R5+ plywood

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Other ways of calculating

Appendix Table A9.36.2.6 Basically calculates the stud/batt combo

Table A-9.36.2.6.(1)A.
Minimum Nominal Thermal Resistance (RSI) to be Made up by Insulation, Sheathing or Other Materials and Air Films in Above-ground Wall Assemblies

Description of Framing or Material	Thermal Resistance of Insulated Assembly			Minimum Effective Thermal Resistance Required by Article 9.36.2.6. for Above-ground Wall Assemblies, (m²·K)/W			R-21.8
	Nominal, (m²·K)/W (ft²·°F·h/Btu)		Effective, (m²·K)/W	2.78	2.97	3.08	3.85
	Insulation in Framing Cavity	Continuous Materials	Entire Assembly	Minimum Nominal Thermal Resistance,[1] in (m²·K)/W, to be Made up by Insulation, Sheathing[2] or Other Materials and Air Film Coefficients			
38 x 140 mm wood at 406 mm o.c.	3.34 (R19)[3]	None	2.36	0.42[4]	0.61	0.72	1.49
		1.32 (R7.5)	3.68	—	—	—	0.17
	3.87 (R22)	None	2.55	0.23	0.42	0.54	1.30
		0.88 (R5)	3.43	—	—	—	0.42
	4.23 (R24)	None	2.66	0.12	0.30	0.42	1.18

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Tall wood

- Lots of framing on lower floors

NECB 2011/2015

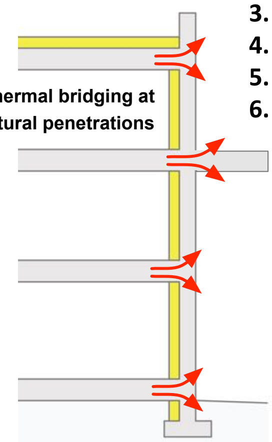
- Many thermal bridges can be ignored, but..
- **1)** In calculating the *overall thermal transmittance* of assemblies for purposes of comparison with the provisions in Section 3.2., the thermal bridging effect of closely spaced repetitive structural members, such as studs and joists, and of ancillary members, such as lintels, sills and plates, shall be accounted for as described in Article 1.1.4.2.

- Wood and steel studs need to be counted
- Repetitive framing like Z-girts

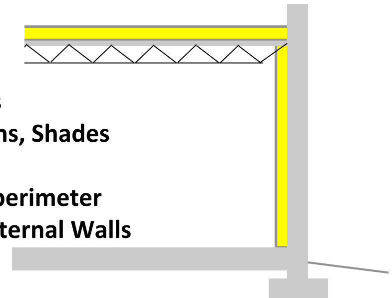
Interior Insulation

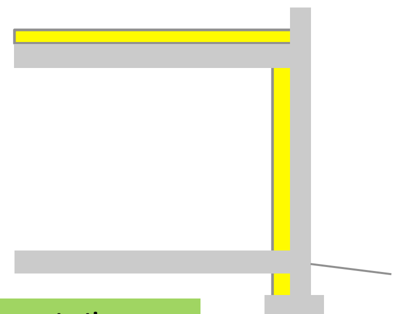
Hard / impossible to get continuous

1. Intermediate Floors
2. Baconies, Projections, Shades
3. Parapets
4. Window and Door perimeter
5. Internal Walls to External Walls
6. At Grade



Thermal bridging at structural penetrations





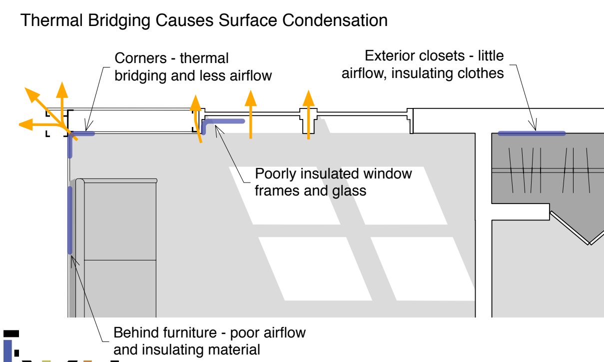
Floors, roofs, slabs cause penetrations

Thermal bridging nightmares

Building Science.com

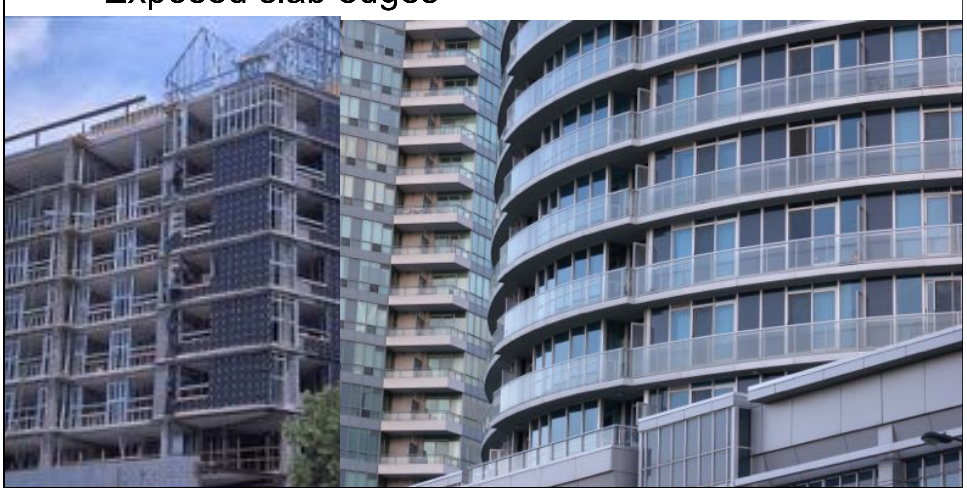
Surface Films @ Thermal Bridges

- Bad thermal bridges cause internal condensation



Thermal Bridge Examples

- Balconies, etc
- Exposed slab edges



Thermal Bridging @ Floor Slabs

R-20
8 ft clear

+

8" slab edge
R-1.2

=

R-??
8'8" full-height

Thermal Bridging Floor Slabs

R-20
8 ft clear

+

8" slab edge
R-1.2

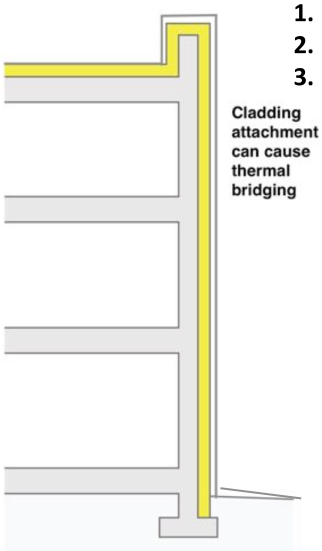
=

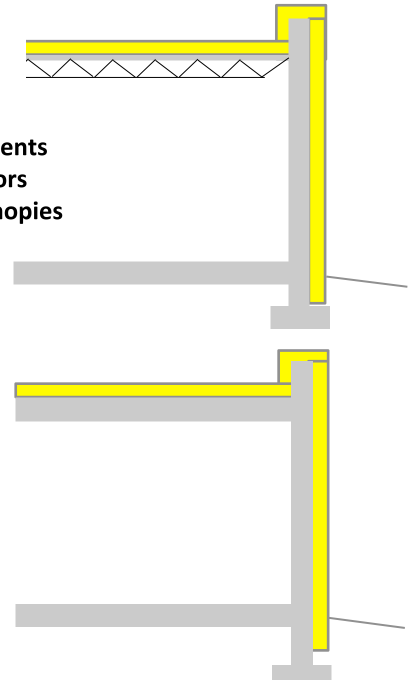
R-9.0
8'8" full-height

Exterior Insulation

Much easier to get continuous

1. **Cladding attachments**
2. **Windows and doors**
3. **Balconies and canopies**

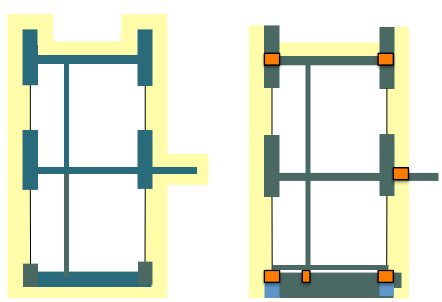




Solutions….

Avoid Thermal Bridges!!!!

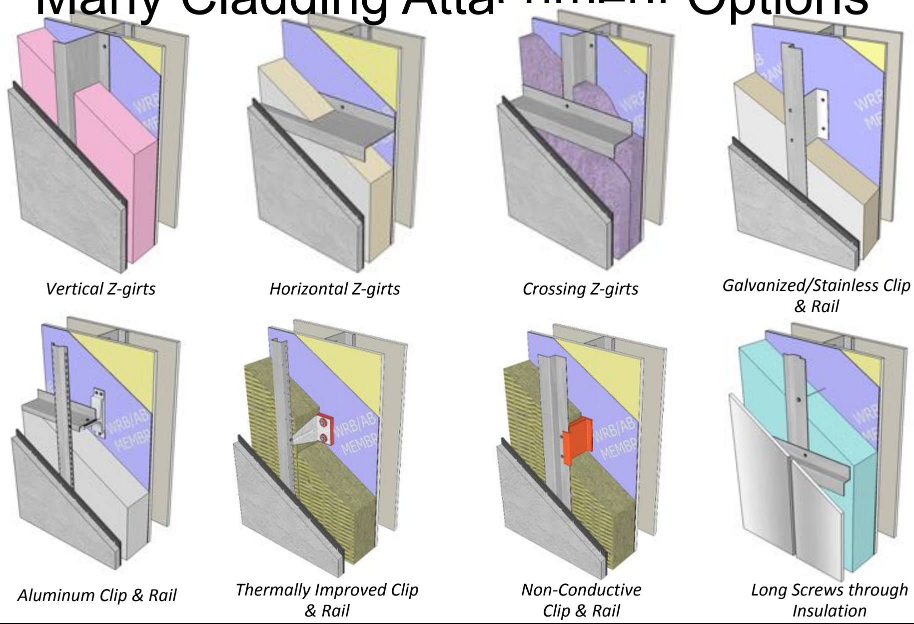
1. **Insulate on outside**
2. **Align window with insulation layer**
3. **Use thermally improved cladding attachment**
4. **Use structural thermal breaks if needed**



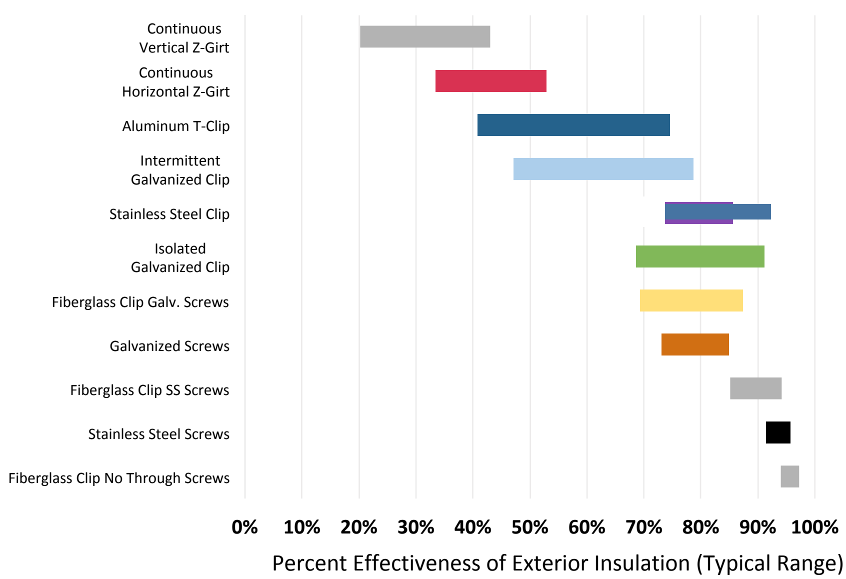
Wrapped Envelope

Thermal Breaks

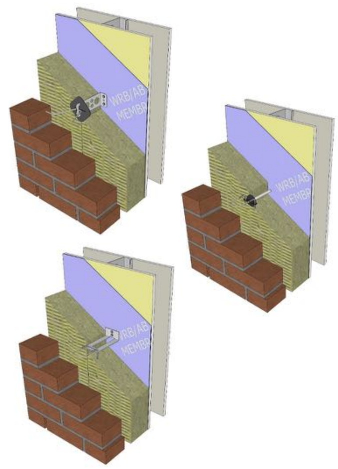
Many Cladding Attachment Options



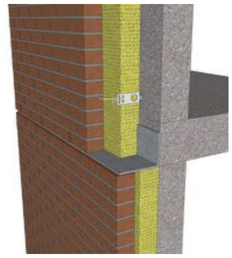
Summary of Cladding Support



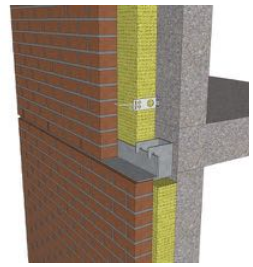
Cladding Attachment: Masonry Ties & Shelf Angles



Brick ties
10-30% loss for most galvanized ties,
5-10% loss for stainless steel



Continuous shelf angles
~40-50% R-value loss



Shelf angle on stand-offs
only ~15%-20 R-value loss

Code Compliance Paths

Project Information

- **Prescriptive**
  - Installed R-value — Limited flexibility, restrictive. No calcs (No Longer)
  - Overall U-value — Simple calculations allow many combination
- **Trade-off**
  - Simple — Easy, calcs account for different window area and quality. Can't trade walls & roofs
- **Performance**
  - Hourly energy model of whole building — Most flexible, hourly computer model, detailed information, difficult to do early stage, requires expertise.

Mandatory minimum HVAC Lighting assumed

What to Include

9.36.2.4. Calculation of Effective Thermal Resistance of Assemblies

1) In calculating the effective thermal resistance of assemblies for the purpose of comparison with the requirements of Articles 9.36.2.6. and 9.36.2.8., the thermal bridging effect of closely spaced, repetitive structural members, such as studs and joists, and of ancillary members, such as lintels, sills and plates, shall be accounted for. (See Appendix A.)

2) Minor penetrations through assemblies, such as pipes, ducts, equipment with through-the-wall venting, packaged terminal air conditioners or heat pumps, shelf angles, anchors and ties and associated fasteners, and minor structural members that must partially or completely penetrate the *building* envelope to perform their intended function need not be taken into account in the calculation of the effective thermal resistance of that assembly.

3) Major structural penetrations, such as balcony and canopy slabs, beams, columns and ornamentation or appendages that must completely penetrate the *building* envelope to perform their intended function, need not be taken into account in the calculation of the effective thermal resistance of the penetrated assembly, provided

a) the insulation is installed tight against the outline of the penetration, and

b) the sum of the areas of all such major structural penetrations is limited to a maximum of 2% of the gross wall area calculated as described in Sentence 9.36.2.3.(2).

What to include

- The big stuff, not the screws, etc

Include in calculation	Exclude from Calculations
Repetitive structural members - Studs - Joists, lintels - Sills, plates	Minor penetrations - pipes, ducts - Packaged air conditioners - Shelf angles, anchors, fasteners
Credit for adjoining unconditioned spaces	Major structural penetrations - Balcony slabs, beams, columns, ornamentation, Provided: insulation is tight to penetrating element - Total area of all major structural penetration is limited to max 2% of wall area

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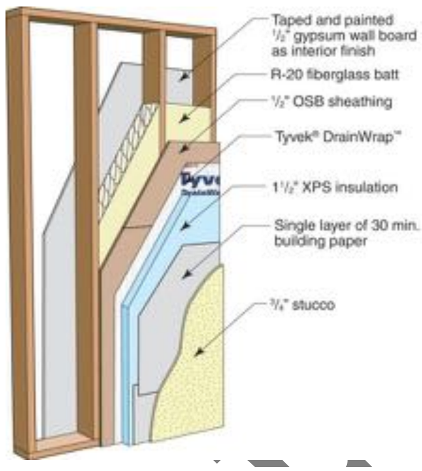
Vancouver test hut sponsored by Dow/Dupont/Hardie
NRCan-sponsored research at University of Waterloo

FIELD MOISTURE STUDIES

Field Testing & Demonstration

RDH

Field Testing & Demonstration



Round1: Interior Wetting & Rain

Round1: Interior Wetting & Rain

Round1: Interior Wetting & Rain

Round1: Interior Wetting & Rain (no exterior insulation)

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Round2: Exterior Wetting & Rain

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Round2: Exterior Wetting & Rain

Round2: Exterior Wetting & Rain

Summary

- Vancouver climate
  - Exterior insulation outperforms standard 2x6
  - Imposed leaks dried out, usually more quickly than standard 2x6

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NSERC/ NRCan -> U Waterloo

- Assess high R-value walls of future
  - High-R? About 50% less heat flow
  - Thus, over R-30
- Moisture performance
  - Higher risk of condensation?
  - Slower drying?
- XPS, Polyiso, EPS, Stonewool available

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R-values

- 2x8 with ccSPF max of R28
- Others reduce heat flow by nearly half (R-32)
- Walls 5 & 6 have no 6 mil poly

Wall	R effective
	(9.36)
1. Double Stud R44	32?
2. I-Joist R44	30?
3. 2x6 Datum	17.7
4. 2x8 ccSPF R40	27.7
5. 2x6 PIC R22 batt	32.4
6. 2x6 2.5" XPS	32.9
7. 2x6 3" MFI	33.0

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Walls isolated from each other

All walls installed

Exterior Insulated Walls

•

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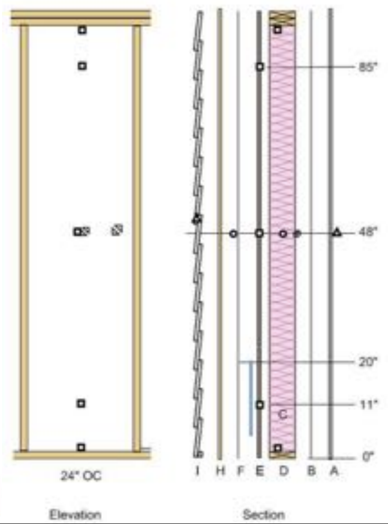
Instrumentation

Datum Fibre Cement, Tyvek, OSB, 2x6, R-22 fibreglass batt, 6 mil poly, latex paint (Base Wall)

•



Assembly

Layer	Function	Description
A	Interior Finish	Painted gypsum board
B	Vapor Control	6 mil poly
C	Studspace	R-22 fiberglass batt
D	Framing	2x6
E	Sheathing	7/16" OSB
F	Membrane	Tyvek
G	Insulation	none
H	Drainage	1x3
I	Cladding	Cement fibre lap siding

Sensor Package

Layer	Code	Location
A	taem	Interior finish, interior face, 48"
C	r/tcnm	Studspace, interstitial, 48"
D	m/tdet	Framing, exterior edge, top plate
D	m/tdel	Framing, exterior edge, bottom plate
E	m/teiu	Sheathing, interstitial, 80"
E	m/teim	Sheathing, interstitial, 48"
E	m/teil	Sheathing, interstitial, 16"
G	r/tinm	Drainage space, interior, 48"
I	tjem	Cladding, interstitial, 48"

- o Relative Humidity and Temperature Sensor Package
- □ Moisture Content Pins and Temperature Sensor Package
- △ Temperature Sensor
- ø Heat Flux Transducer

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Results

- Measured for over two years
  - Currently undergoing spring rain wetting
  - Drill down on drying performance
- More results are being developed
  - More rain leak studies this spring

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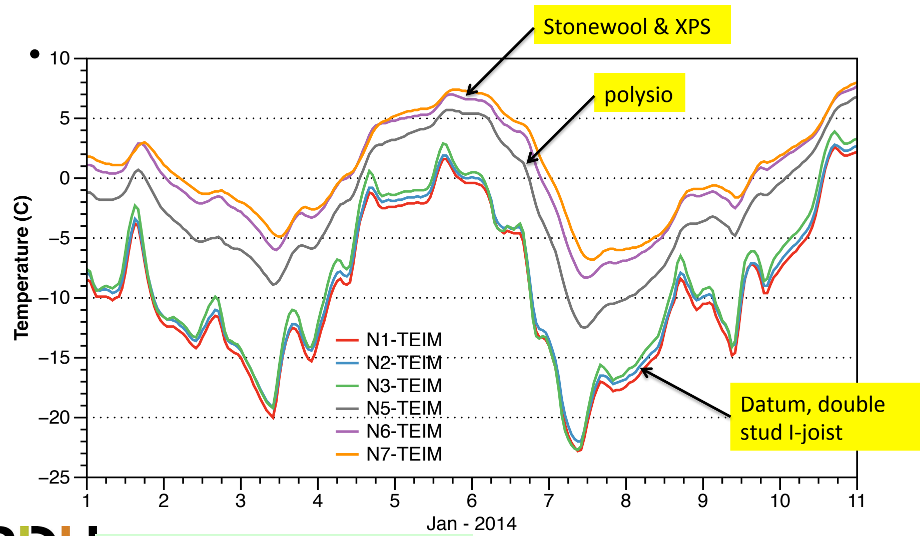
OSB Sheathing Temperature



RDH **Polyiso performs at less than R12**

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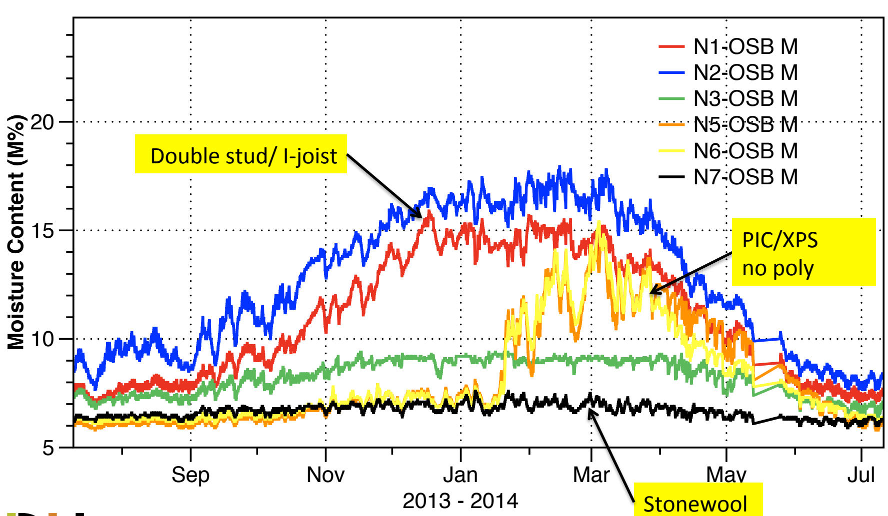
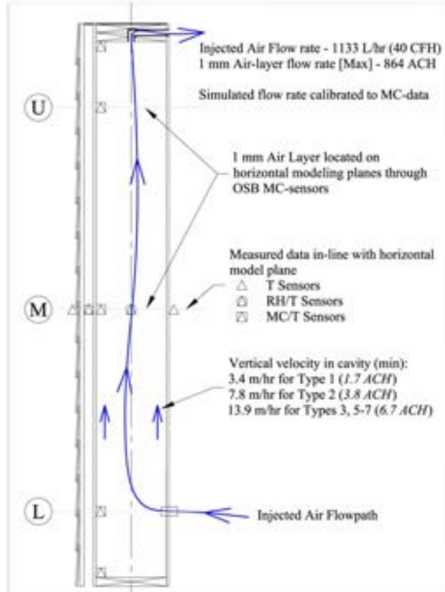
North OSB MC

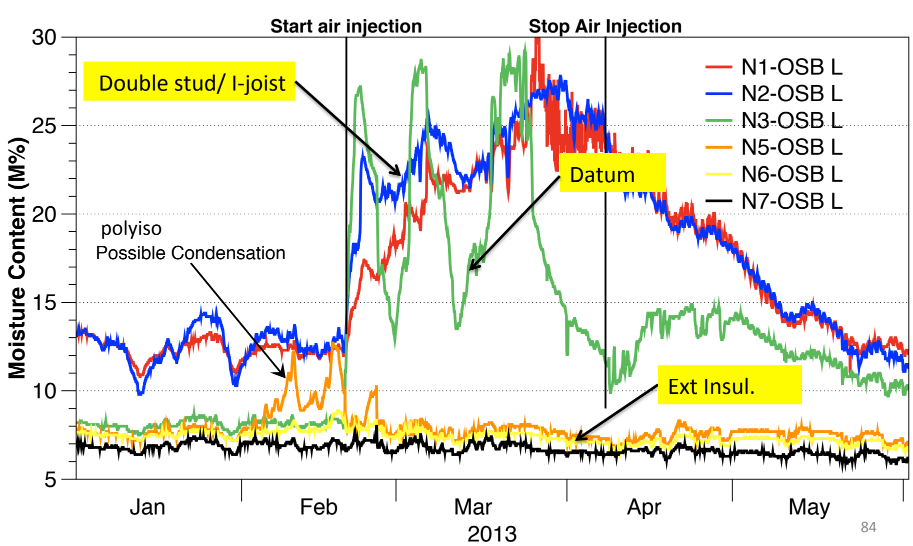


RDH **Double stud is near the edge in Waterloo**

Calibrated Air leak



Winter Air Leakage



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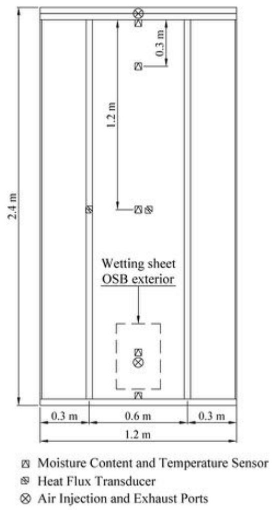
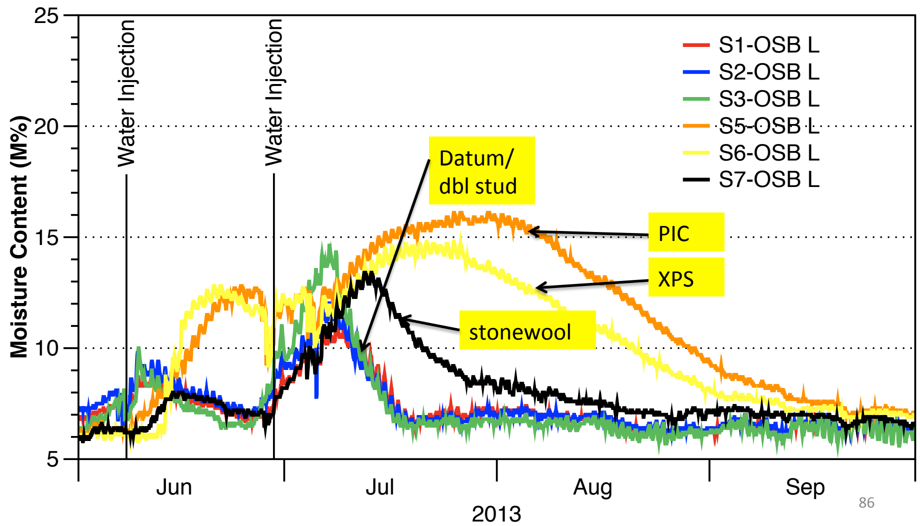
Calibrated water leak



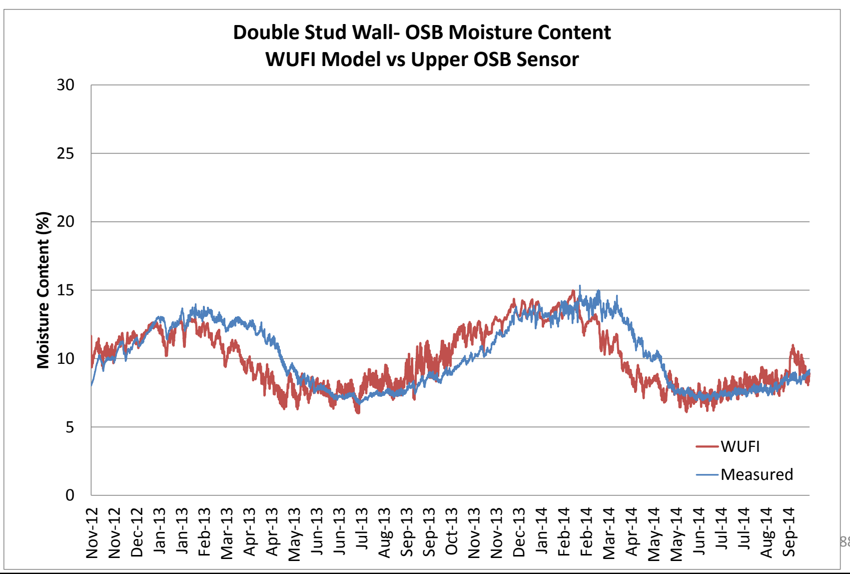
Water leakage

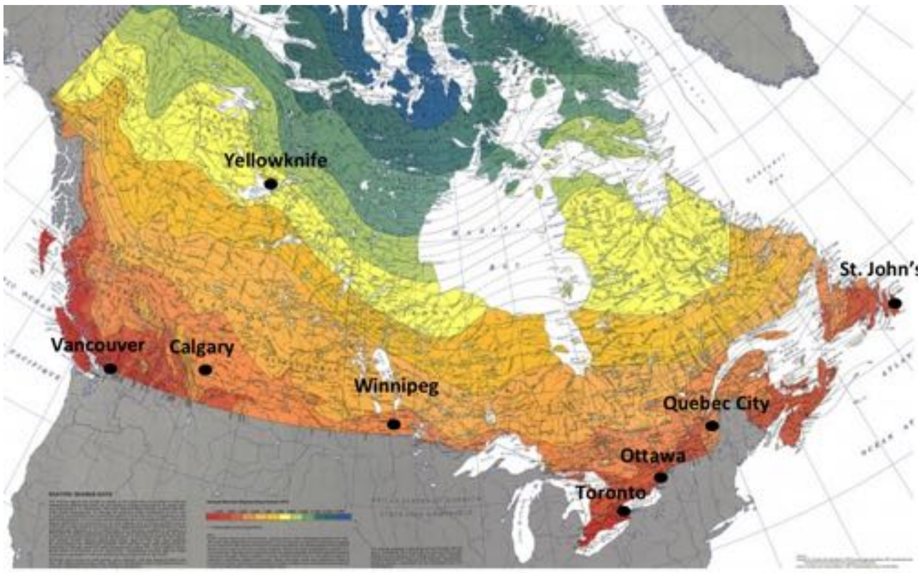


Modeling

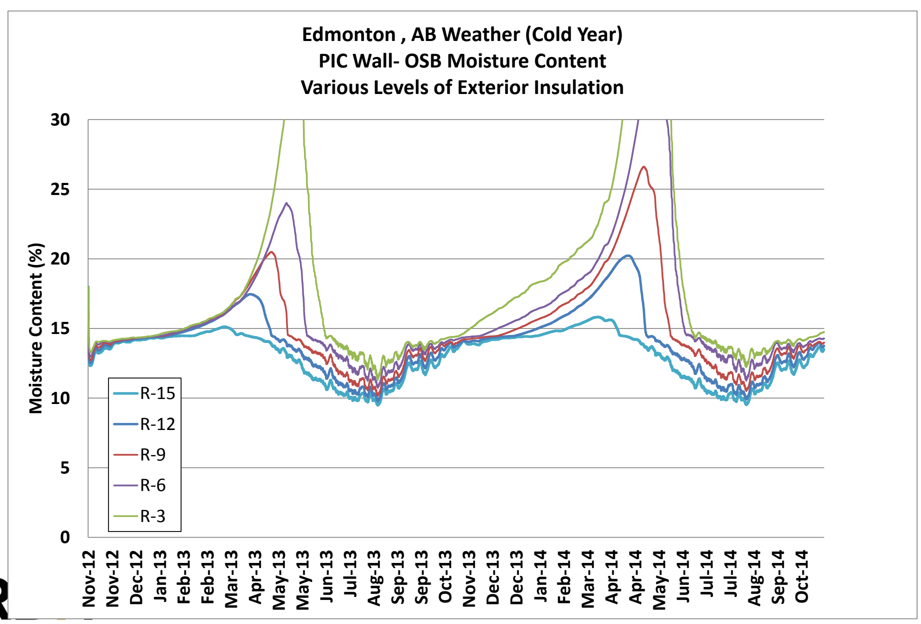
- Computer model WUFI
- Extrapolate
  - Different climates
  - Varying Interior RH
  - Different insulation levels

Model vs Measure

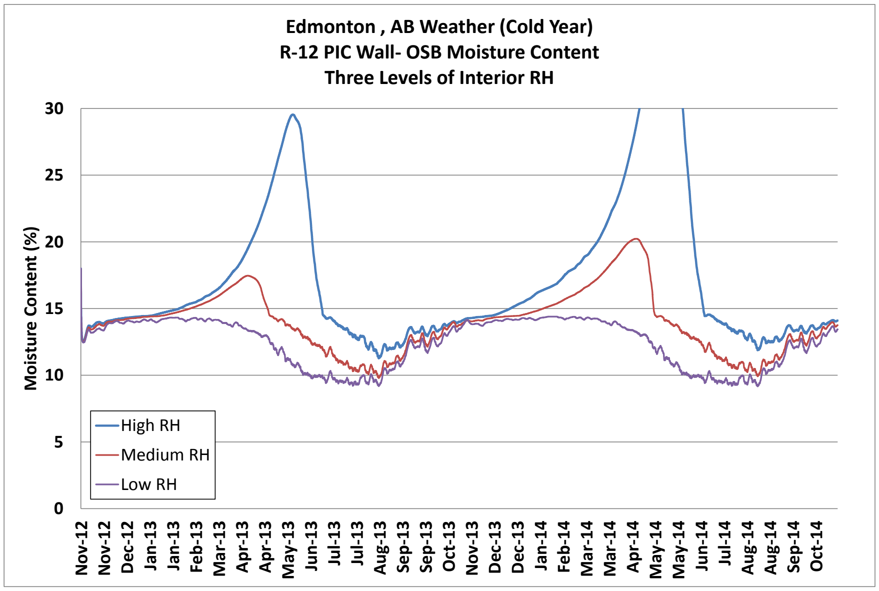




Extension: R-value



Interior RH **really** matters



Real walls

- Real assemblies fail if
  - air leakage is too much (and RH is high)
  - Too much rain wetting (often windows)
- Re-run models..
  - Account for some leakage of air and rain

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Response to Rain & Air leak

■ = MC < 20%, no mold growth ■ = MC is 20 to 28%, potential for mold growth ■ = MC > 28%, moisture problems expected, this design is NOT recommended

						Vancouver			Toronto				St. Johns		
						Ave. Annual Temp 9 °C			Ave. Annual Temp 7 °C				Ave. Annual Temp 4 °C		
	Wall Construction					HDD 2910, 304 mm Driving Rain			HDD 3800, 77 mm Driving Rain				HDD 4881, 291 mm Driving Rain		
Wall	Cavity Insulation	Cavity Depth	Exterior Insulation	Ext. Insul. Thickness	Vapour Control	No Leakage	1% Rain leak	2% Rain leak	No Leakage	1% Rain leak	2% Rain leak	5% Rain leak	No Leakage	1% Rain leak	2% Rain leak
Datum	Fiberglass	5.5 "	none	0	Polyethylene sheet	11%	15%	22%	11%	11%	12%	15%	11%	15%	22%
PIC	Fiberglass	5.5"	polyiso-cyanurate	2"	Latex paint+primer	11%	16%	24%	13%	13%	17%	23%	15%	25%	35+%
					Polyethylene sheet		35+%	35+%		11%	15%	35+%		35+%	35+%
XPS	Fiberglass	5.5"	extruded polystyrene	2.5 "	Latex paint+primer	11%	16%	24%	13%	13%	17%	23%	15%	25%	35+%
					Polyethylene sheet		35+%	35+%			15%	35+%		35+%	35+%
EPS	Fiberglass	5.5"	expanded polystyrene	3.0"	Latex paint+primer	11%	17%	27%	14%	15%	18%	25%	17%	26%	35+%
					Polyethylene sheet		35+%	35+%			20%	35+%		35+%	35+%
RW	Fiberglass	5.5"	rockwool insulated sheathing	3.0"	Latex paint+primer		13%	18%			12%	16%		13%	20%
					Polyethylene sheet	9%	12%	18%	9%	9%	9%	13%	8%		20%
Double Stud	Cellulose	11.25"	none	0	Polyethylene sheet	13%	15%	20%	13%	13%	16%	19%	14%	17%	20%

General Notes:

a. Walls are residential wood frame with light-colored, thin cladding facing north: this is a worse-case scenario for cold-weather diffusion wetting
b. Results are for OSB sheathing. Plywood sheathing values will be equal or lower. OSB permeance is always over 60 ng/Pa·s·m² in exterior sheathing applications.
c. Sheathings of DensGlas, FiberBoard, and Gypsum Board are all very vapor permeable and hence will have lower moisture contents
d. Thicker foam will always result in lower wintertime sheathing moisture contents
e. Effective Air Barrier is assumed to be installed, as is proper rain control
f. MC values are for inner 3 mm OSB sheathing

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Study Conclusions

- Increasing exterior insulation R-value
  - Safer wall
  - IF enough exterior insulation used
- Control interior RH in winter
- Poly can be removed if enough insulation exterior to 2x6 (about R15 in Winnipeg)

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AIR CONTROL

Airtightness: System is key

- Why increase airtightness?
  - Save energy (*as insulation levels increase airtightness becomes more important*)
  - Typically 30% of heating is air leakage
  - Improve air quality: where is air coming from?
- Need to add *controlled* ventilation
- Codes/ standard are beginning to demand it
- Can only really know tightness by testing
  - Must begin to test large buildings

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Air Barriers Requirements

- Requirements
  - **Continuous (most important)**
  - **Strong**
  - **Stiff,**
  - **Durable,**
  - **Air Impermeable (least important)**
- Easily 1/3 of total heat loss is due to air leakage in well-insulated building

Commercial Buildings:
Often an exterior air barrier is the only practical solution

Air Barriers Are Systems

Materials

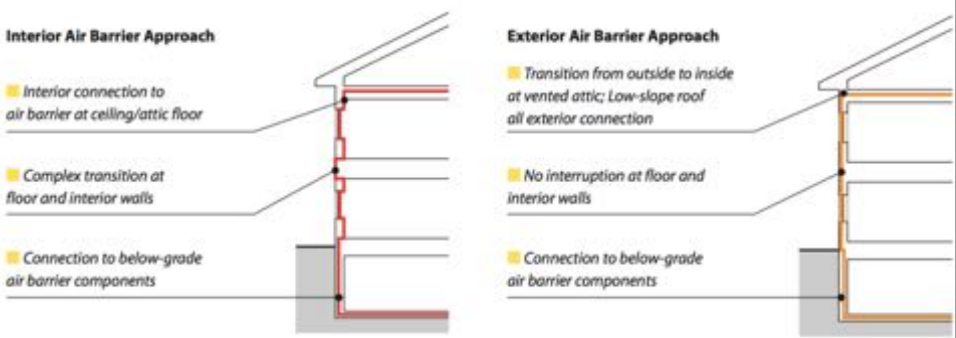
Components

Accessories

Whole Building Airtightness

Exterior Air Barriers

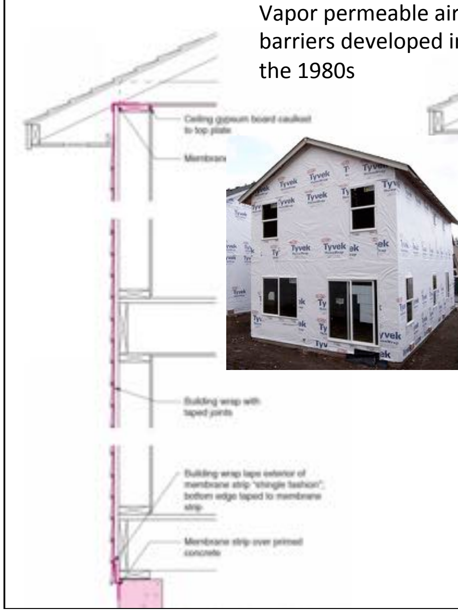
- Many more penetrations and details with interior air barrier approach
- Exterior is preferred today

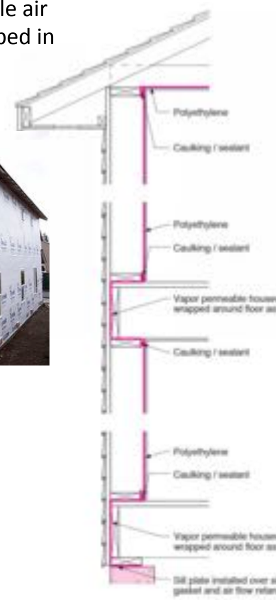


Why Exterior Air Barriers versus Interior?

Vapor permeable air barriers developed in the 1980s

Vapor barrier air barriers first deployed in 1960s





1980's Poly Air-Vapor barrier

- Label of "vapor barrier" created lots of confusion
- Flexible membrane hard to seal
- Separate "service" walls developed
- Still possible, just not best or most economical

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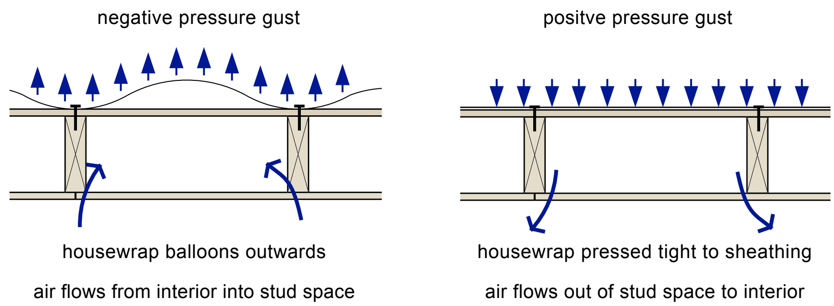
Air-Water-Vapor Membranes

- Often thin layers, membrane or fluid-applied
- *Can be*
  1. Water control (vapor permeable, not airtight), **or**
  2. Air & water control (vapor permeable), **or**
  3. Air, water & vapor (vapor impermeable).
- Examples
  – Building paper, untaped housewrap, sealed and supported housewrap, fluid applied, peel and stick

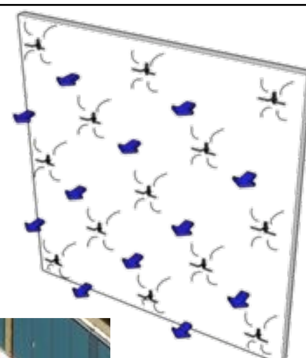
Fully-adhered vs. Mechanically Fastened

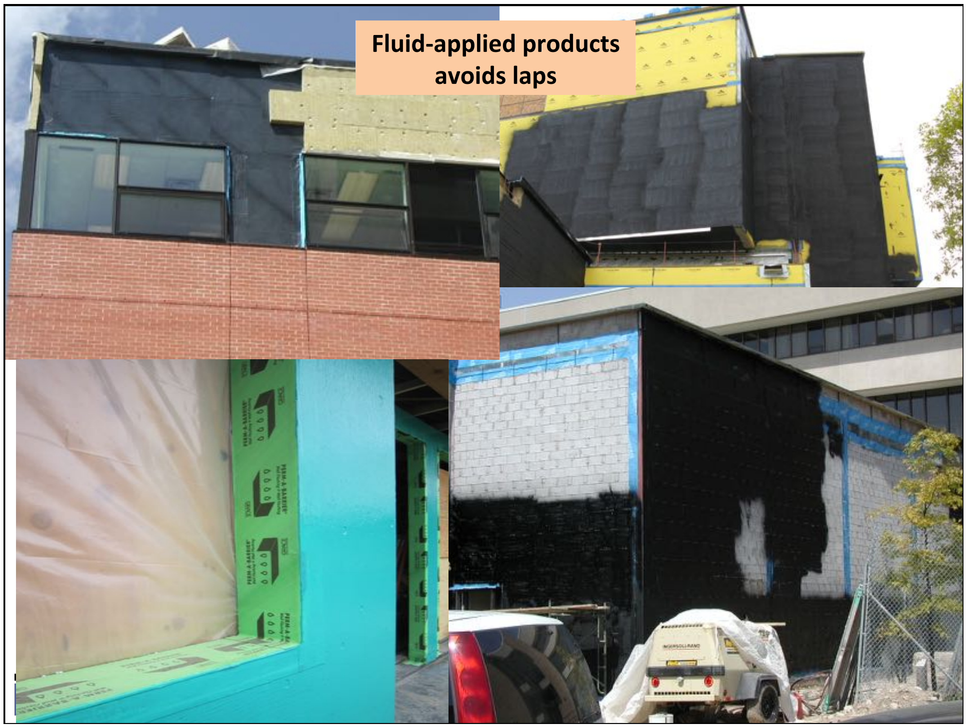
→ Bellows action: airtight but moves air!

→ Fully-adhered: uses substrate as support and increases airtightness



Fully-adhered preferred





Fully-adhered, vapor barrier

Requires insulation on exterior to manage condensation

Self-Adhered Air-Water Barrier

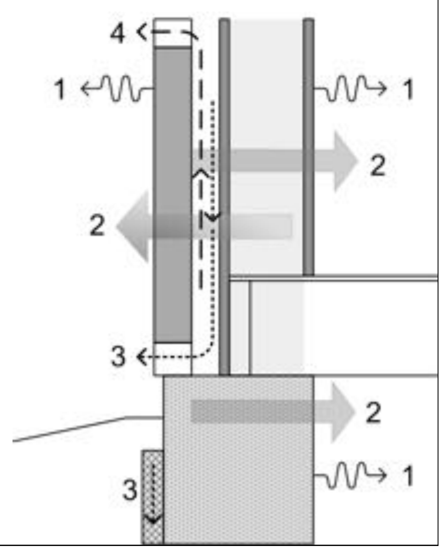
- Self-adhered membrane sheets (vapor permeable or impermeable) applied to sheathing along with tapes/self-adhered membranes at interfaces

Taped Rigid Foam Sheathing

VENTS AND VENTILATION

Wall Drying Mechanisms

1. Drainage
2. Surface Evaporation
3. Through-wall
   i) Diffusion
   ii) Convection
4. Within-wall Convection = Ventilation



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1. Drainage

- Removes rain leaks / condensation faster than any other mechanism
- Drainage gap… small sizes work, even less than 1 mm
- Flashing!

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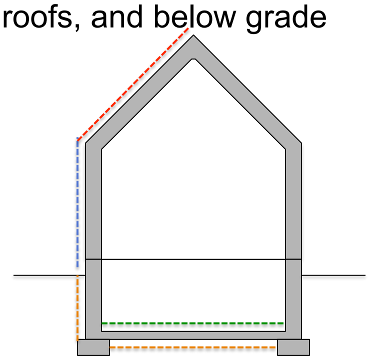
Drainage vs Venting

- Gaps allows
  - Water flow (Drainage) and
  - Air flow (Ventilation)

- Drainage removes free liquid water
- Then dry absorbed / adsorbed water
  - Diffusion, capillary, *and* ventilation
- Cavity Design plays pivotal role

Mind the Gap

- Gaps are used in many technical applications
  - A reliable (unblockable), but very small, gap is needed to provide drainage
  - A larger gap is needed to allow venting (airflow)
- Used in walls, roofs, and below grade



3. ii) Ventilation

- Intentional airflow behind cladding bypasses vapor resistance of cladding
- Allows faster drying
- Controls damaging inward diffusion
- How big of a gap is needed?
  - ¼” 6mm To 1” 25 mm is likely range
  - Even smaller may help

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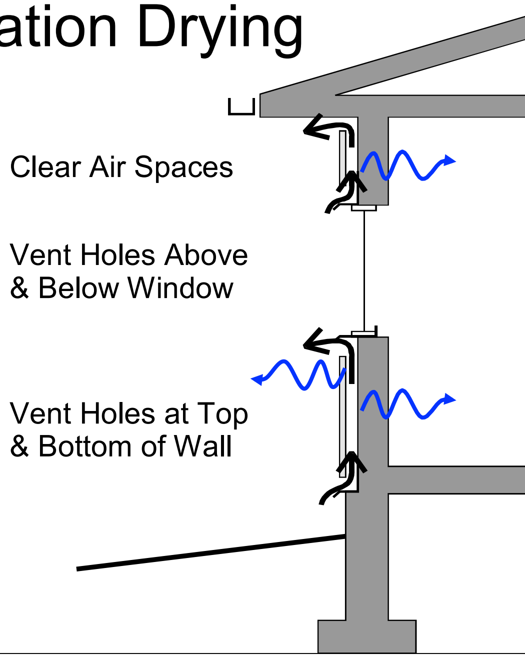
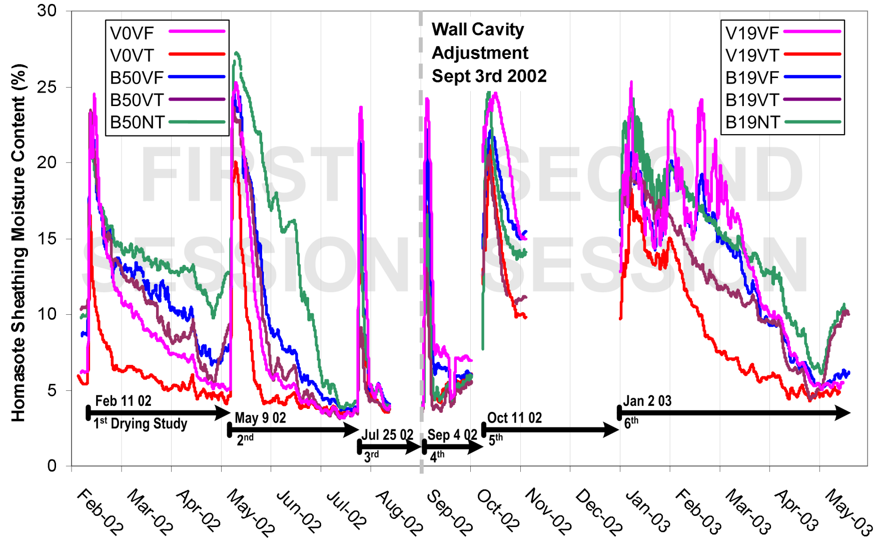
Ventilation Drying

- Ventilation
- Diffusion
- Important for some systems that retain drain water
- Helps for small leaks



UW – Field Testing (ASHRAE)

Drying of Sheathing – 9 wettings x 1.8kg



3. i) Diffusion Drying

- **Ventilation**
- **Diffusion**

- **Important for some systems that retain drain water**
- **Helps for small leaks**

Clear Air Spaces

Vent Holes Above & Below Window

Vent Holes at Top & Bottom of Wall