Rain Control 1

John Straube

Outline

- Driving Rain load (and wind)
- Penetration forces
- Risk, expectation exposure
- Rain Control Strategies
- Flashing & Details
- Window door openings
- Curtainwalls, precast

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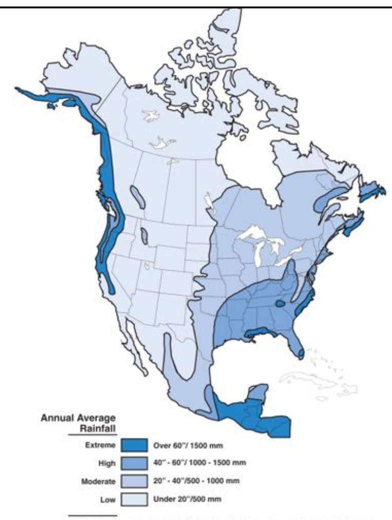
Rain and Driving Rain

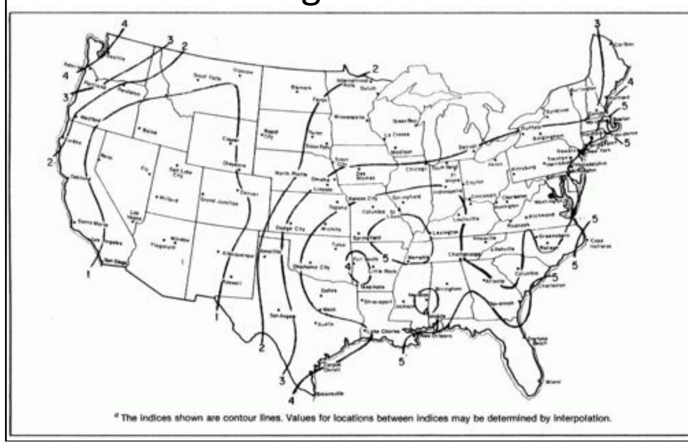
- Climate effects
- Getting rain from the clouds to the building

Controlling Driving Rain Penetration

- Understand driving rain to control it
  - Result of wind and rain
  - Building shape and height affects it
  - Enclosure design choices



Driving Rain Index




Rain Event Duration
Fig. 6. Annual WDR event duration normals for the contiguous United States for the period 1971 to
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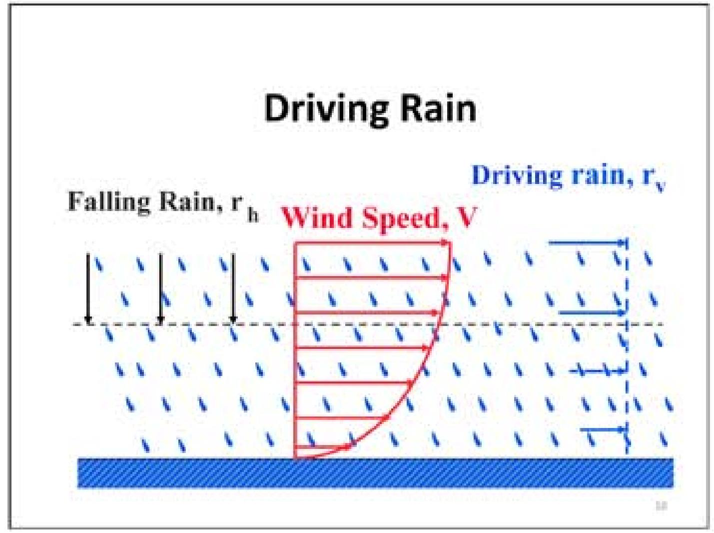
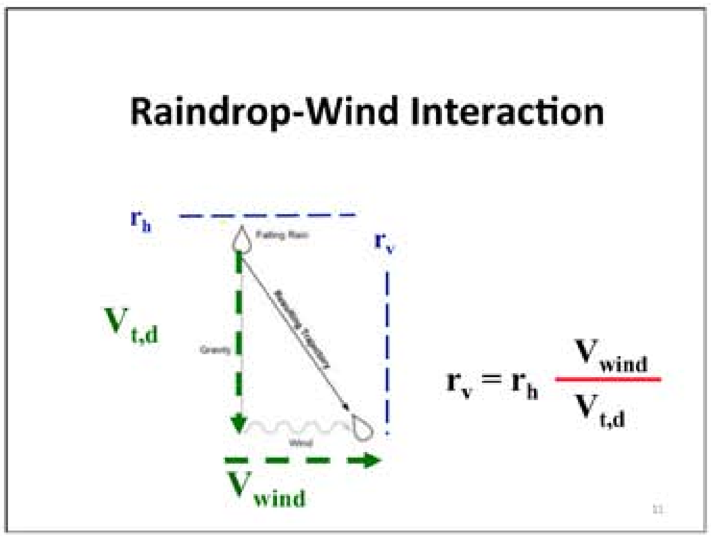
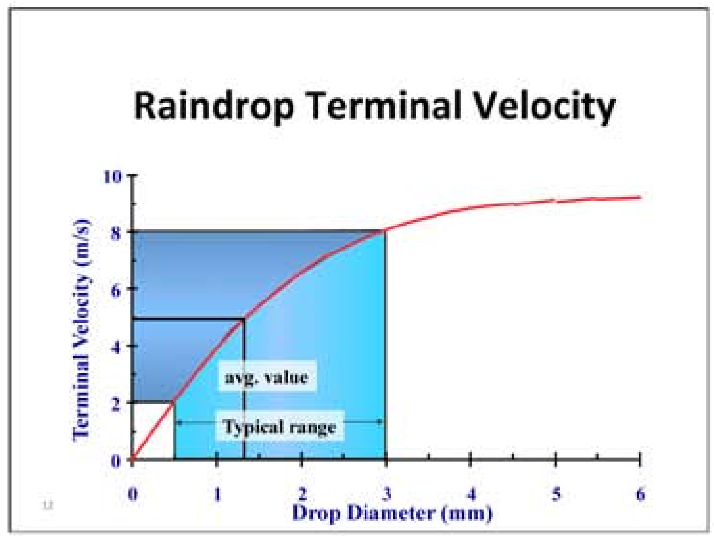
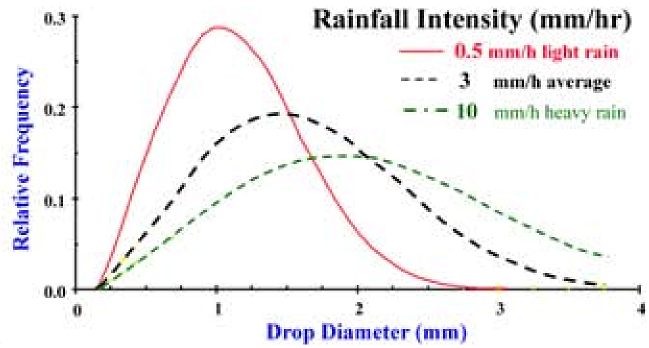

Driving Rain
Driving rain, r_v
Falling Rain, r_h
Wind Speed, V


Raindrop-Wind Interaction
r_h
r_v
$V_{t,d}$
V_{wind}
$r_v = r_h \frac{V_{wind}}{V_{t,d}}$


Raindrop Terminal Velocity
Terminal Velocity (m/s)
Drop Diameter (mm)
avg. value
Typical range
0
2
4
6
8
10
0
1
2
3
4
5
6

Raindrop Size Distribution



Driving Rain in Free Wind

- Based on
  - terminal raindrop velocity
  - Raindrop size vs rainfall intensity

Driving rain through vertical plane r_v

$r_v = V_{wind} / V_{d,t} \cdot r_h$

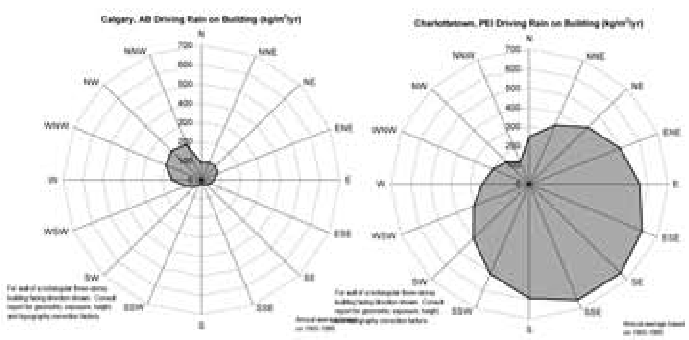
$r_{bv} = DRF \cdot r_h \cdot V_{wind}$

DRF, Driving Rain Factor

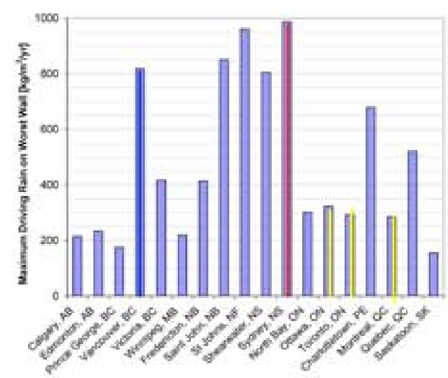
- Calculated factor for raindrops size, V_{wind} / V_{dt}

- *Annual average* DRF is about 0.2
  - Ranges from 0.18 to 0.25 depending on climate

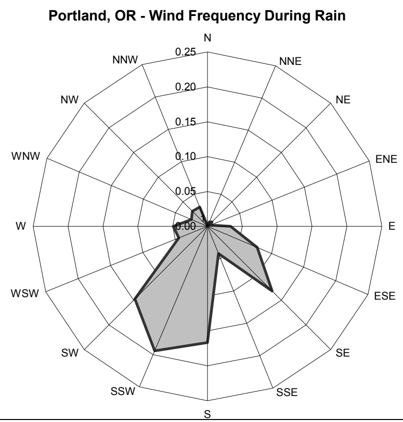
Calgary vs Charlottetown



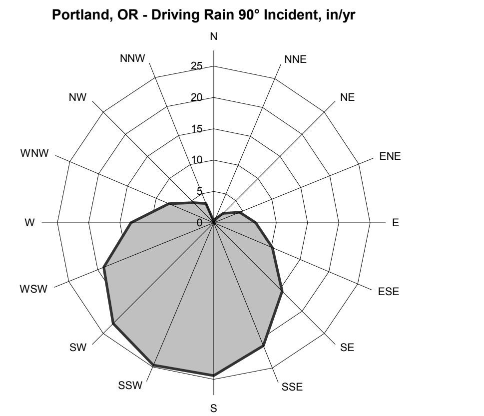
Max Driving Rain vs City



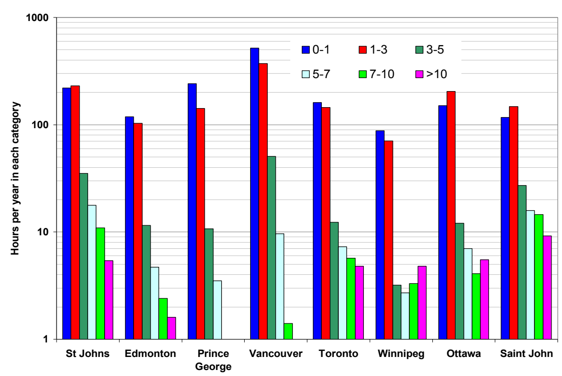
Wind During Rain: Portland



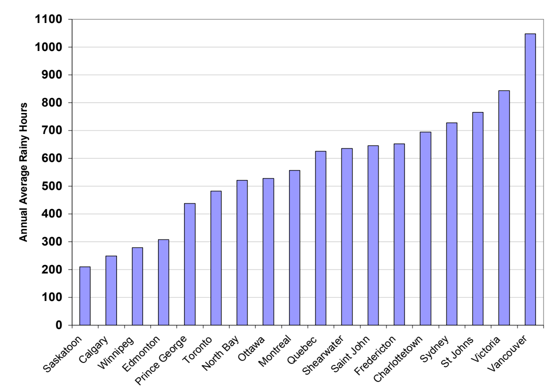
Total Rain Deposition: Portland



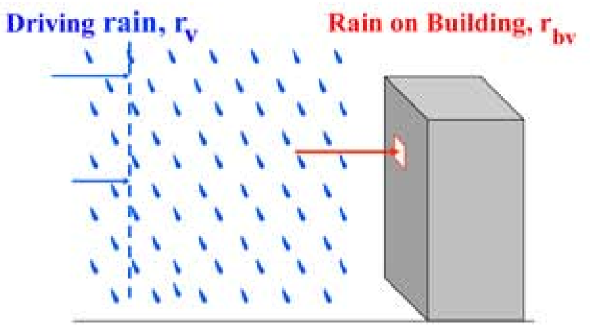
Rainfall Intensity



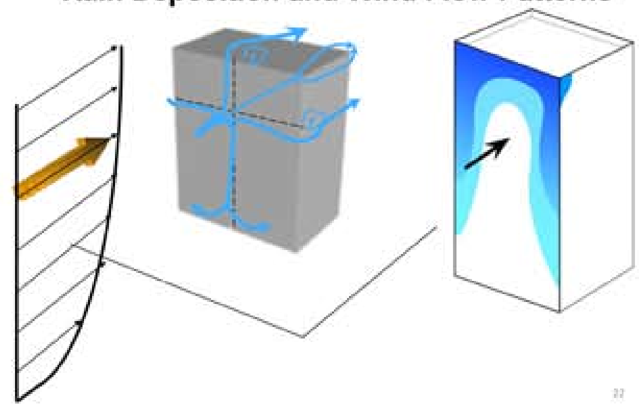
Other Statistics: Hours of Rainfall



Rain and Buildings

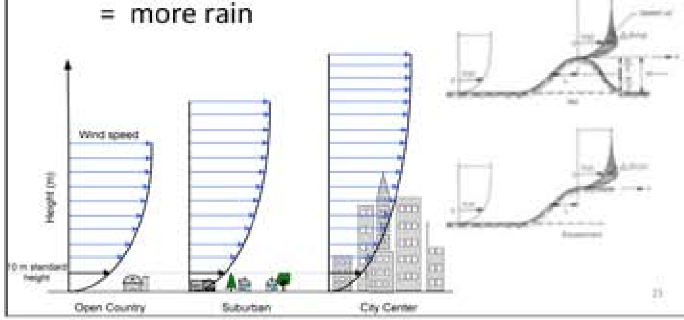


Rain Deposition and Wind Flow Patterns

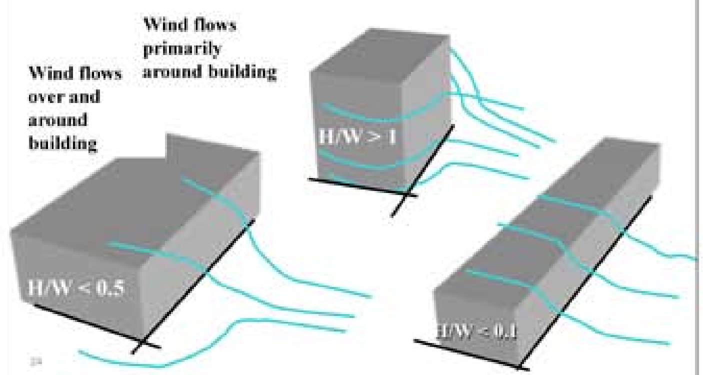


Windspeed (Exposure) = Driving Rain

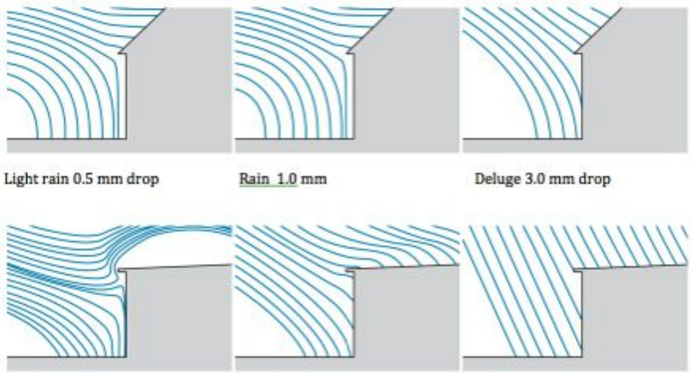
- Tall exposed buildings exposed to more wind = more rain



Effect of Building Shape

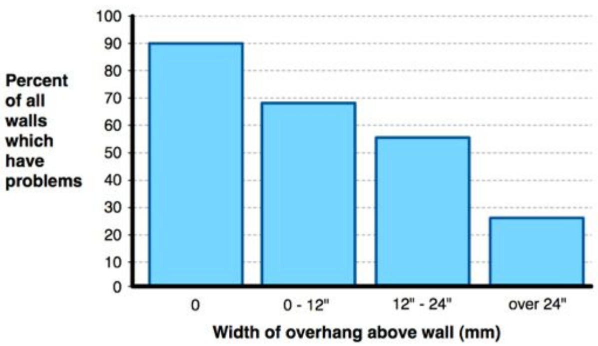


Dropsize & Windspeed matter



Rain drop Trajectories in a 5 m/s 11.2 mph wind

Overhangs



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Simple Prediction

- Driving rain on a vertical building surface r_{bv}

$r_{bv} = V_{wind} / V_{d,t} \cdot RDF \cdot r_h$

$r_{bv} = DRF \cdot RDF \cdot r_h \cdot V_{wind}$

- RDF, Rain Deposition Factor:
  - Empirical factor
  - converts free wind to rain on building
  - accounts for airflow around building

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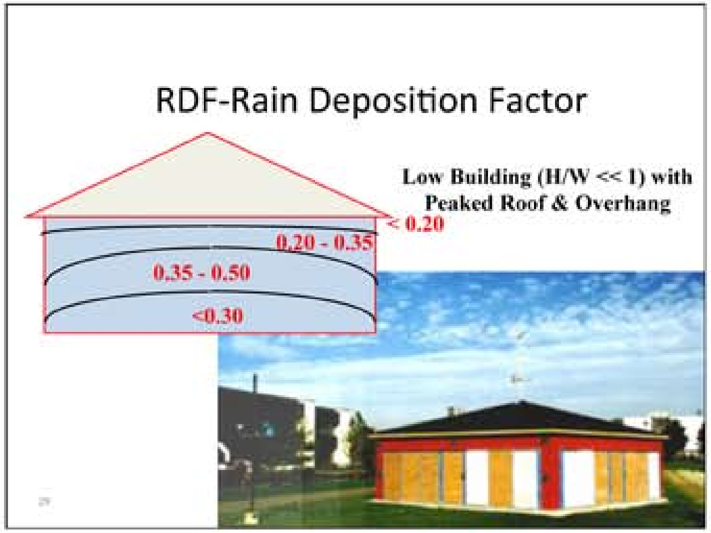
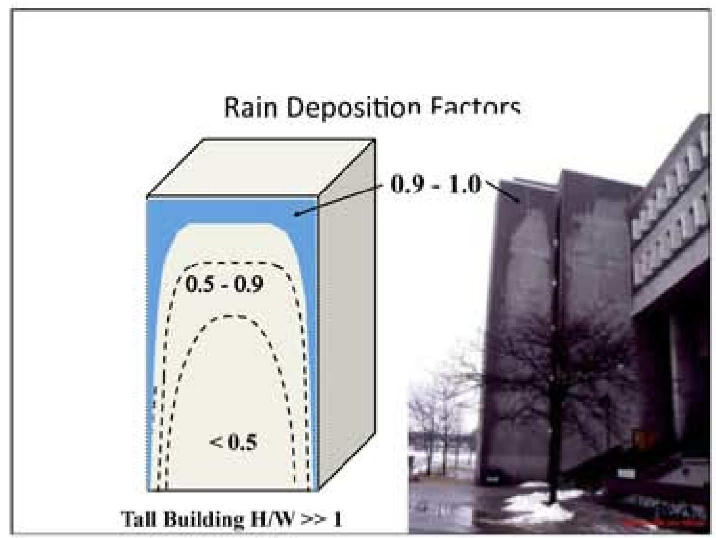
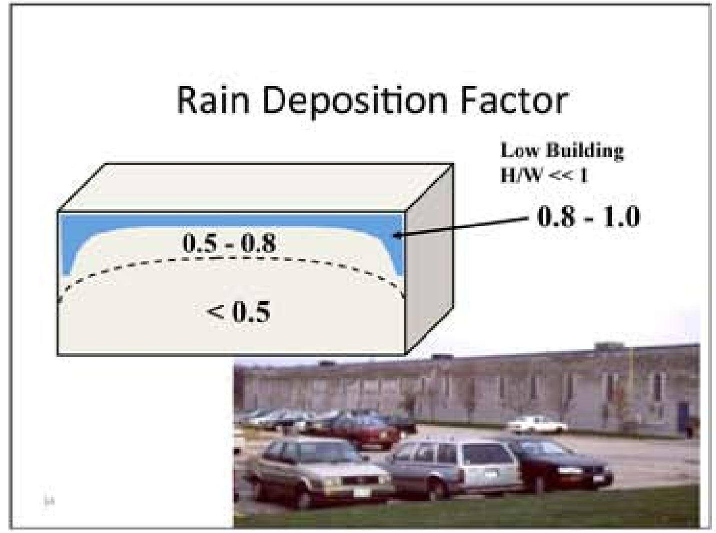
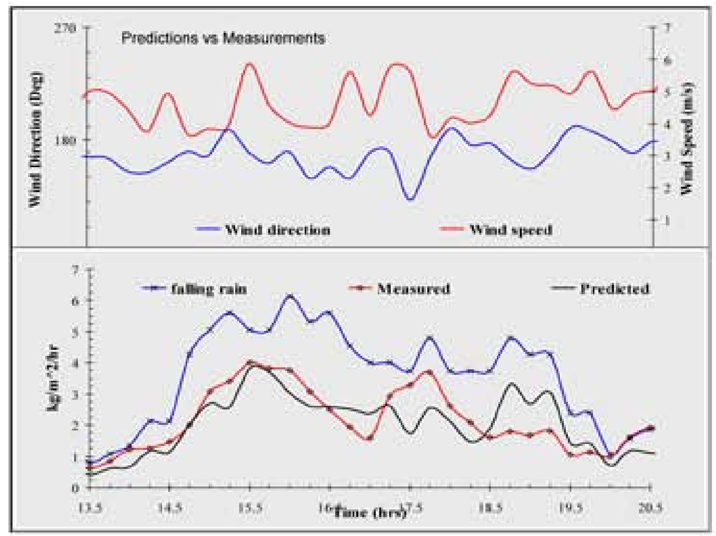

RDF-Rain Deposition Factor
Low Building (H/W << 1) with Peaked Roof & Overhang
< 0.20
0.20 - 0.35
0.35 - 0.50
<0.30


Other field measurements NRCC/IRC funded
9.0 m
3.6 m
6.9 m
6.9 m


Rain Deposition Factors
0.9 - 1.0
0.5 - 0.9
< 0.5
Tall Building H/W >> 1


Rain Deposition Factor
Low Building
H/W << 1
0.8 - 1.0
0.5 - 0.8
< 0.5


Predictions vs Measurements
Wind Direction (Deg)
Wind Speed (m/s)
Wind direction
Wind speed
falling rain
Measured
Predicted
kg/m^2/hr
Time (hrs)

Assessing Risk

Risk	Relationship to Rain-Penetration Problems
Rainfall	As the amount of rainfall increases, the risk increases
Exposure	As the exposure to rainfall increases, the risk increases
Shape and Surface	As shape and surface features increase rain deflection and shedding respectively, the risk decreases
Water Penetration Resistance	As the water penetration resistance of the assembly increases, the risk decreases
Moisture Tolerance of Assembly	As the moisture tolerance of the materials that comprise the assembly increases (e.g., masonry and concrete vs. wood and steel) the risk decreases
Drying Potential	As the ability of an assembly to dry increases due to the climate, design, or both, the risk decreases
Workmanship	As craftsmanship, inspection, & testing of the construction quality increases, risk decreases

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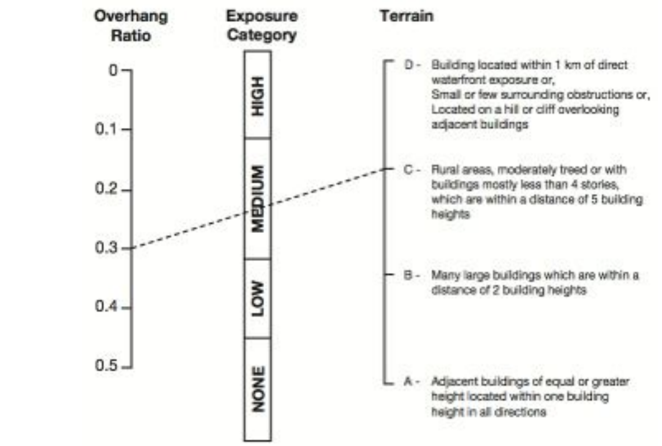

CMHC Best Practise Guide: RDH Building Engineering

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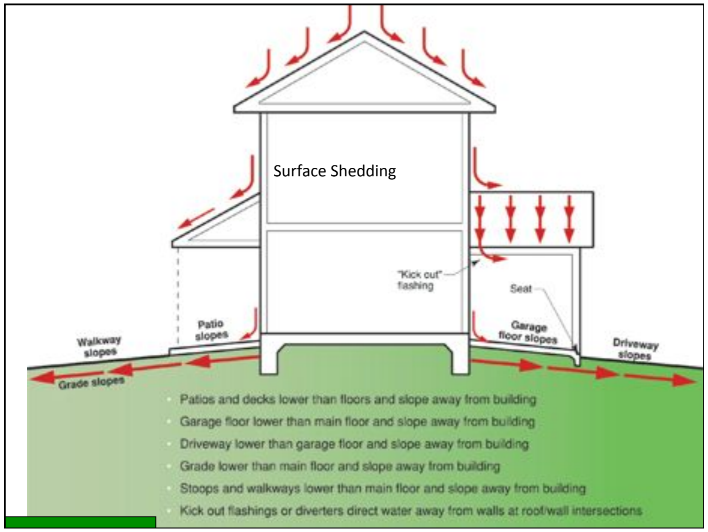
Rain Control Philosophy

- The Three D's
  - Deflection
  - Drainage/Exclusion/Storage
  - Drying

Controlling Rain Penetration

- *Deflection*
  - reduce water on building
  - Shed and redirect water away
  - slope surfaces, use exposed flashing/drips
- *Drainage / Exclusion / Storage*
  - enclosure design
  - provide drainage, or storage or barrier
- *Drying*
  - allow any remaining water to dry



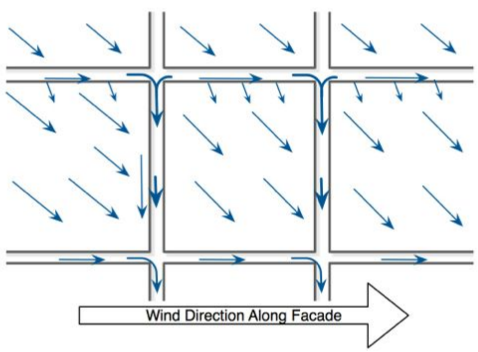
Shedding: Surface Drainage

- Surface Drainage Accumulates on Tall Buildings
- Redistribute and Control via
  - Drips
  - Overhangs
- Protect Windows, Saddles, etc.

If it doesn't get wet, it won't leak

J. Straube 2002 42

Surface flows



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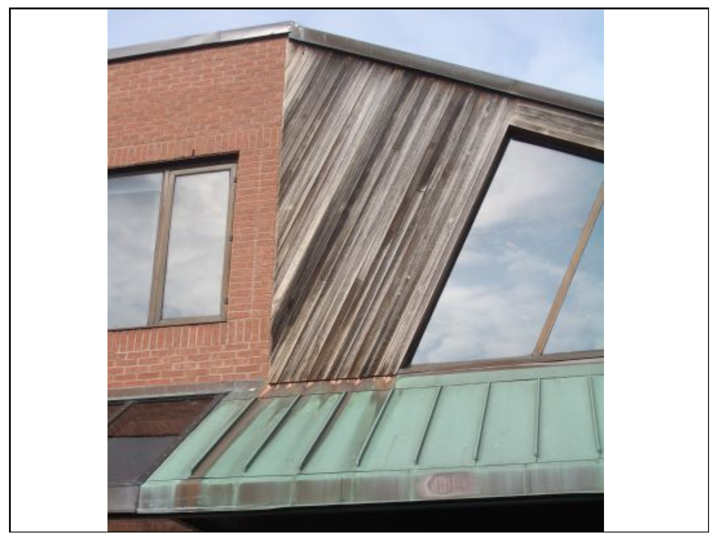
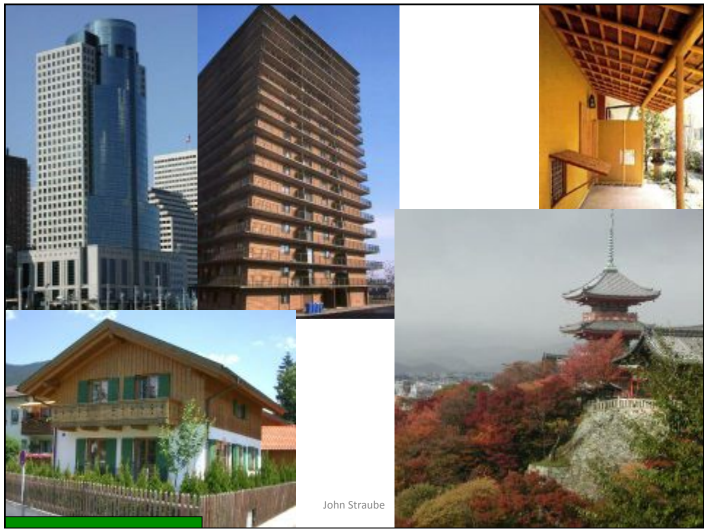
Hilton Toronto

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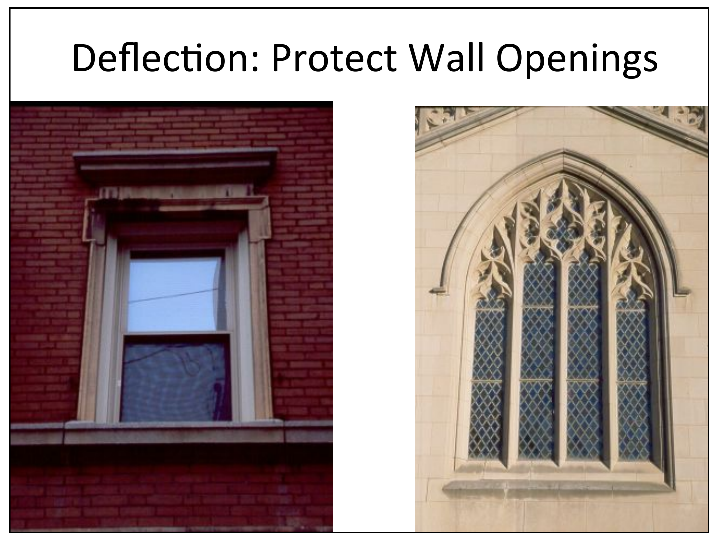
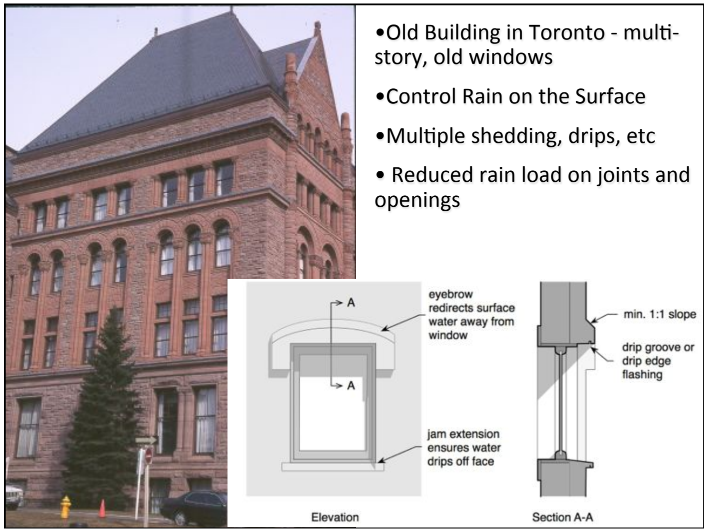
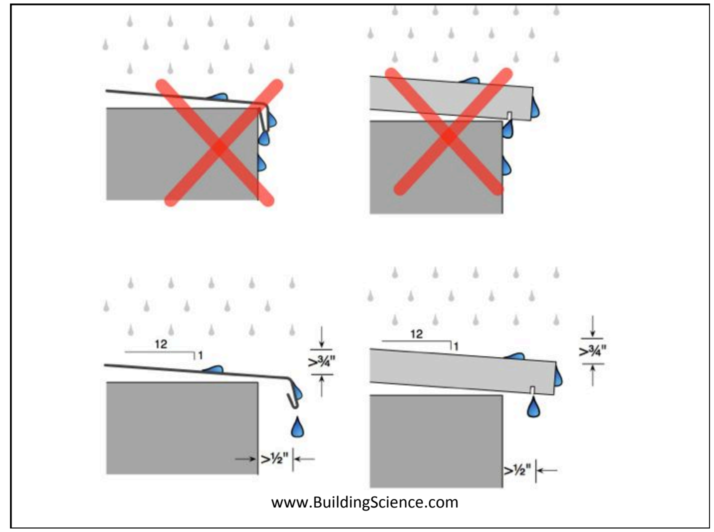
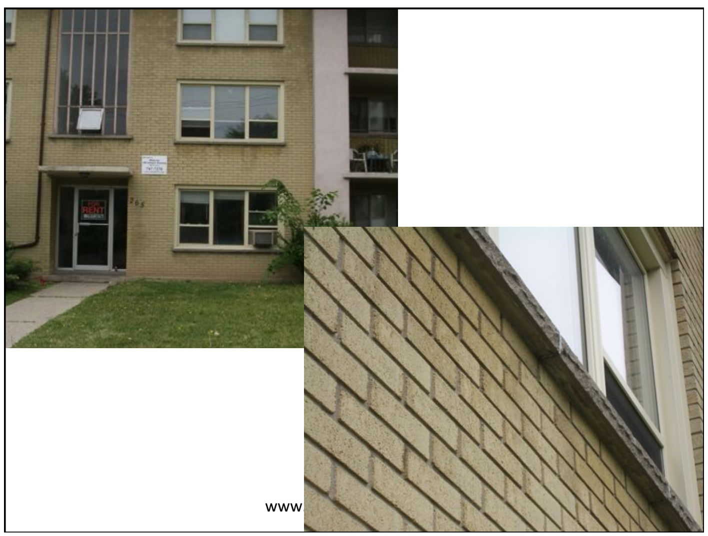
Durable Wooden Buildings
Forbidden City
Southern Germany
Lake Baikal
COURT...HOUSE
New Zealand


Overhangs Surface - Drainage - Shelter


Deflection: Protect Wall Openings


•Old Building in Toronto - multi-story, old windows
•Control Rain on the Surface
•Multiple shedding, drips, etc
• Reduced rain load on joints and openings
eyebrow redirects surface water away from window
jam extension ensures water drips off face
min. 1:1 slope
drip groove or drip edge flashing
Elevation
Section A-A


12
1
>¾"
>½"
www.BuildingScience.com


www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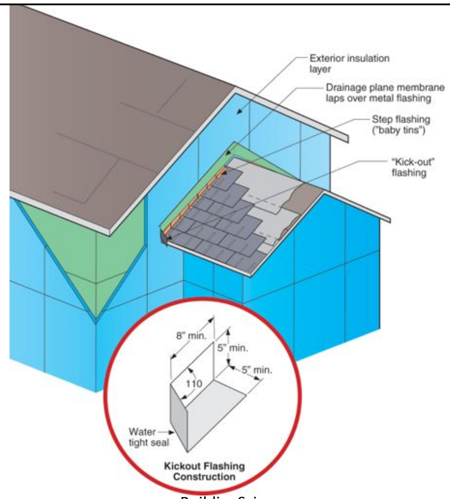
Joints protected
•slope
•end dams
John Straube 2


Slopes
Drips


End Dams


SHOPPERS PLA


Modern surface details



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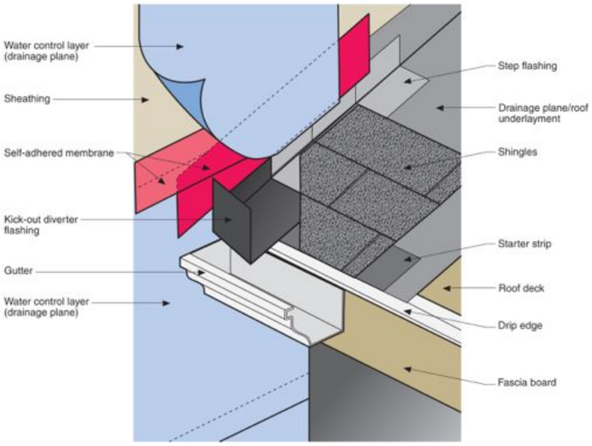

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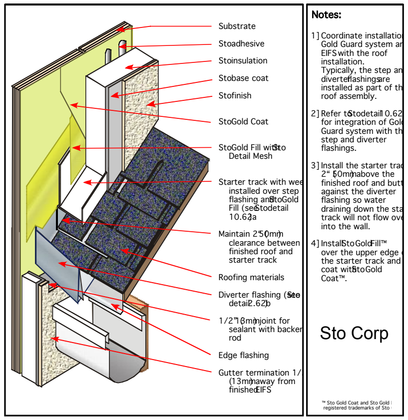
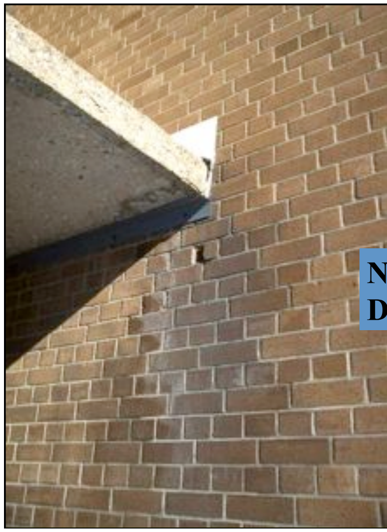
Diverter Flashing



Another simple, but critical, detail



Need for kick-out or Diverter flashing

005

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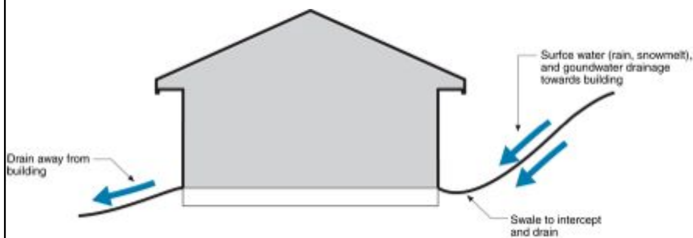
Base Splash



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Water Penetration Forces

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Why do enclosures leak?

1. Gravity (downhill through holes)
2. Capillarity (small gaps)
3. Air pressure *assists* through large holes
4. Kinetic energy (for direct entry)

- Gravity and capillarity most situations
- Capillarity misunderstood
- Gravity ignored / wishful thinking

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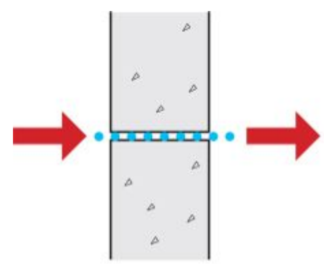
Direct Energy



Rain droplets can be carried through a wall by their own momentum

Rain entry by momentum can be prevented by designing wall systems with no straight through openings

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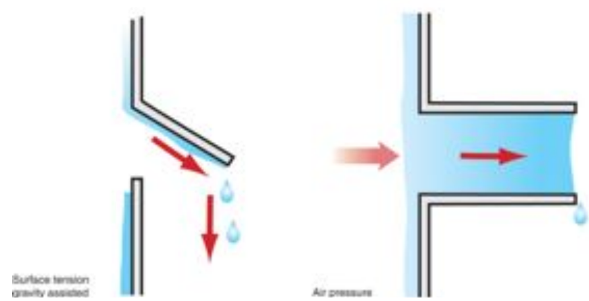

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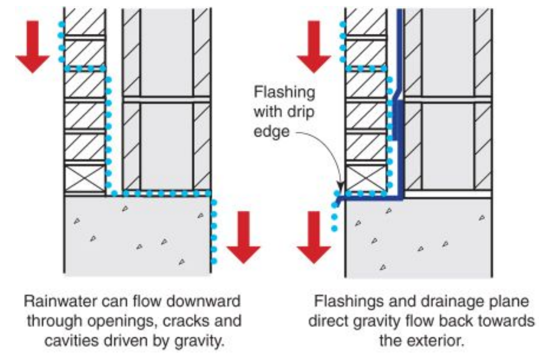
Gravity



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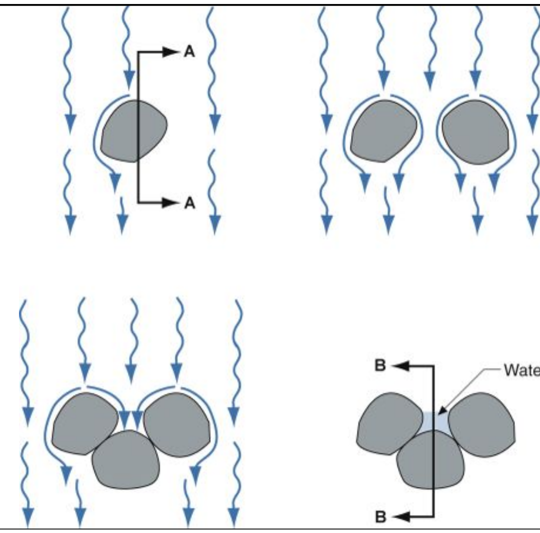
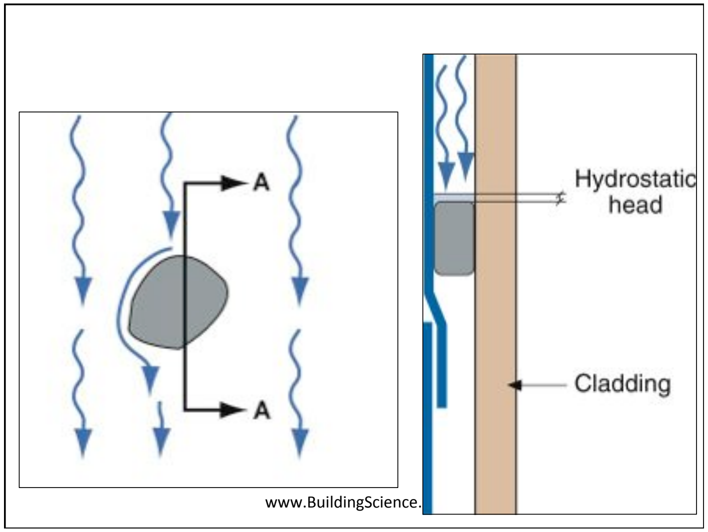
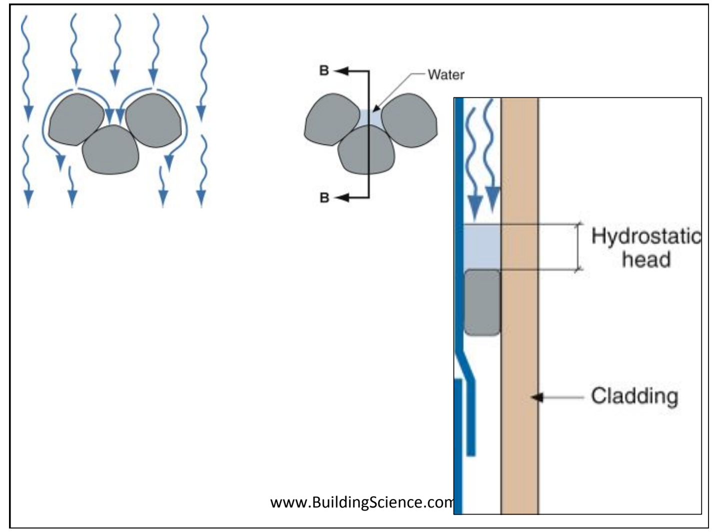
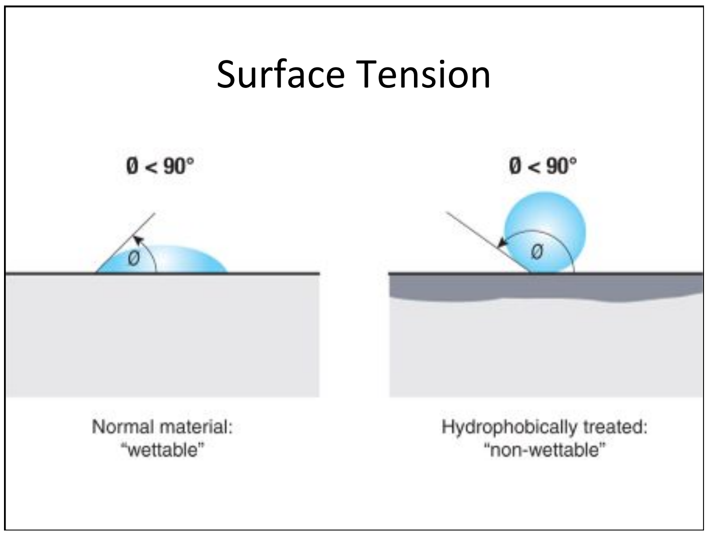
Gravity

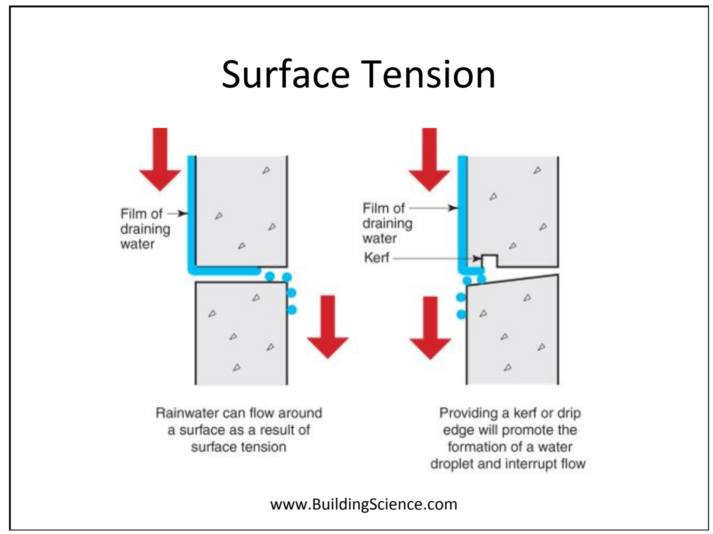
- Hydrostatic
- 1” w.c. = 250 Pascals




A
A
Hydrostatic head
Cladding
www.BuildingScience.


B
Water
B
Hydrostatic head
Cladding
www.BuildingScience.com


Surface Tension
Ø < 90°
Ø
Ø < 90°
Ø
Normal material:
"wettable"
Hydrophobically treated:
"non-wettable"


Surface Tension
Film of draining water
Film of draining water
Kerf
Rainwater can flow around a surface as a result of surface tension
Providing a kerf or drip edge will promote the formation of a water droplet and interrupt flow
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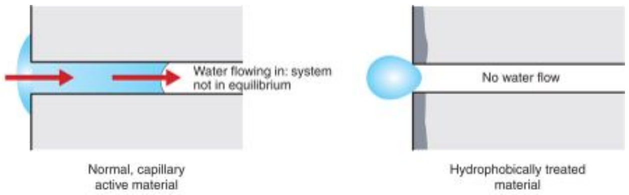
Capillary



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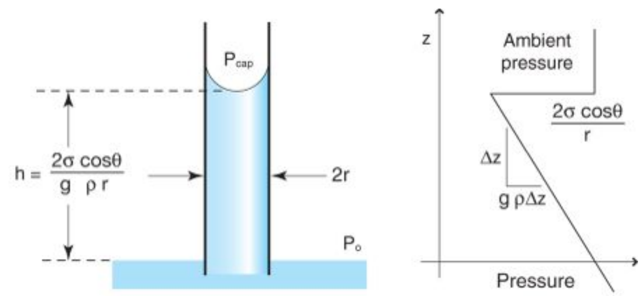
Capillary Suction



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Capillary Suction

crack width/ pore radius			Capillary Suction	
[inch]	[mm]	[Pa]	[psf]	[inch w.c.]
1/2	12.7	11.3	0.24	0.05
1/8	3.2	45.4	0.95	0.18
1/16	1.6	90.7	1.89	0.36
1/32	0.8	181	3.79	0.73
1/100	0.254	567	11.8	2.28
1/1000	0.025	5669	118	22.8

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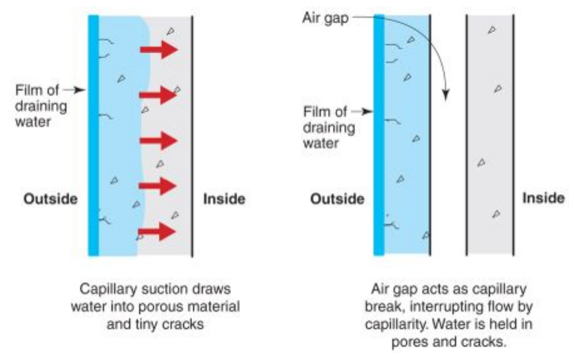
Capillary Suction



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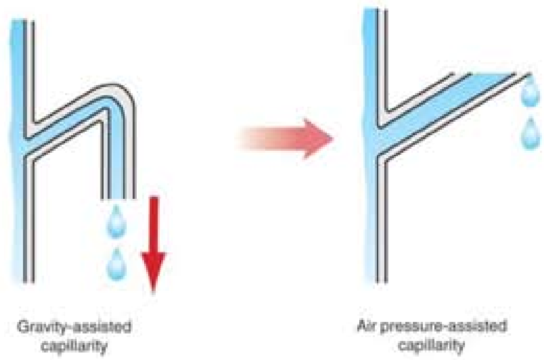
Capillary Assisted Forces



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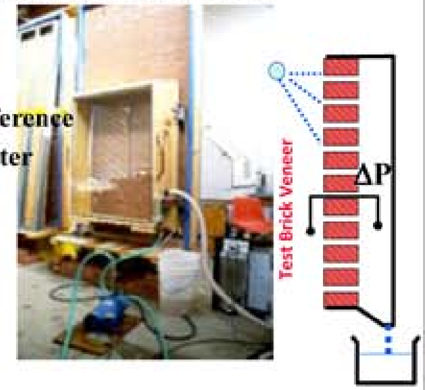
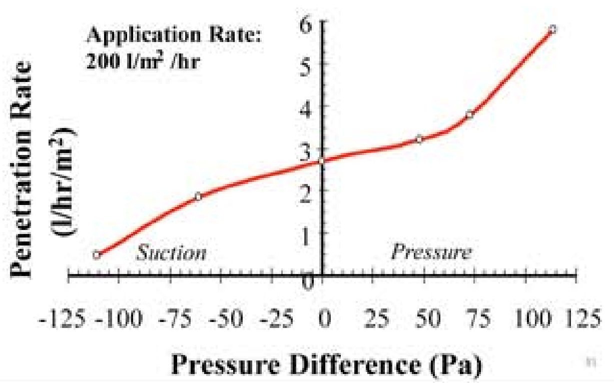
Veneer Water Permeance Test

- Applied spray
- imposed pressure difference
- measured drained water
- plotted results:
  - versus time
  - versus pressure at steady state



Pressure and Masonry Permeance



Wind Pressure

- $P_{stag} = ½ \rho V^2$.

  Where P_{stag} is the stagnation pressure [Pa or psf]

  ρ is the air density [N/m³ or pounds/ft³] and

  V is the air speed [m/s or mph].

ASCE 7-05 recommends the following:

- $P_{stag} = k \cdot V^2$

  Where k=0.00256 [psf] or k=0.613 [Pa].

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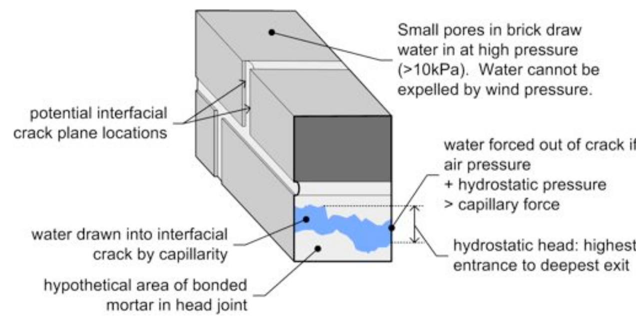
Head Joints Leak!

Brick Leakage



Wind Pressure

[mph]	[Pa]	[psf]	[inch w.c.]	[m/s]
4.5	2.5	0.05	0.01	**2.0**
6.7	5.5	0.12	0.02	**3.0**
10	12.1	0.25	0.05	4.5
15	27.5	0.57	0.11	6.7
20.2	**50**	1.04	0.20	9.0
22.4	61.3	1.28	0.25	**10.0**
25	76.6	1.60	0.31	11.2
28.6	**100**	2.10	0.40	12.8
45.2	**250**	5.22	**1.00**	20.2
50	308	6.42	1.24	22.4
55.9	383	8.00	1.54	25.0
60	441	9.2	1.77	26.8
63.9	**500**	10.4	**2.0**	28.6
88.4	956	**20**	3.84	39.5
90	**1000**	20.9	**4.0**	40.4
111	**1500**	31.3	6.0	49.5
120	1755	36.6	7.0	53.5
125	1916	**40**	7.7	55.9
140	2395	**50**	9.6	62.5

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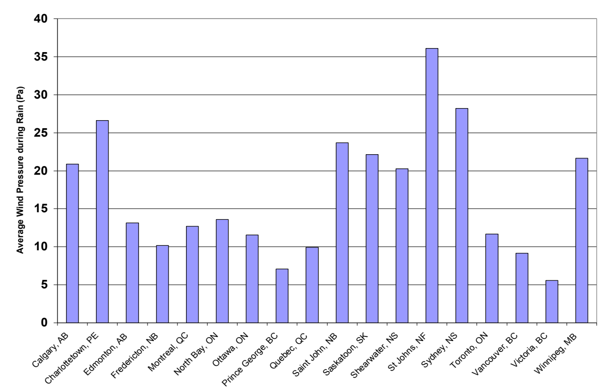
Average pressure during rain



Existing Tests vs Reality

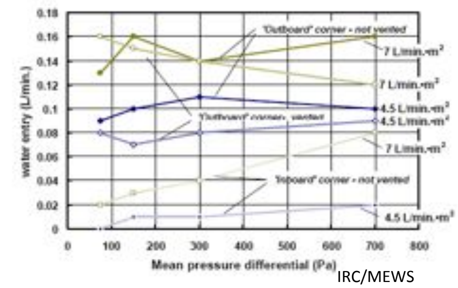
- ASTM E 514
  - 2.3 L/min-m^2
  - 500 Pa
  - Not less than 4 h
- ASTM E 331
  - 3.4 L/min-m^2
  - 137 Pa
  - 15 min

- Driving Rain and Wind Analysis (CMHC Data)
  - Average 0.012 L/min-m^2
  - 10 Pa
  - Extreme 0.17 L/min-m^2
  - 84 Pa
- Leaks?

11-12-08 John Straube 97

Leakage is f(deposition)

- Pressure matters less than deposition rate



IRC/MEWS

Figure 2.22 – Water entry (L/min.) through 6-mm diameter deficiencies in corner of window as a function of mean dynamic pressure differential for both non-vented and vented rainscreens having the second line of defence not sealed

Pressure often not important

Note: Rain deposition rates typically <<0.1 l/min/m2

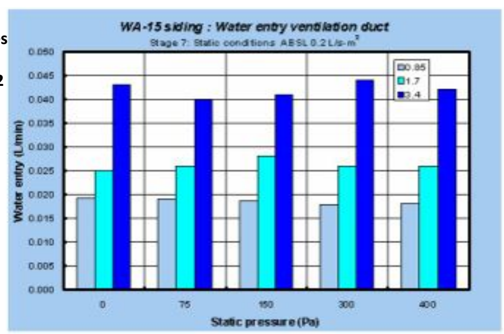


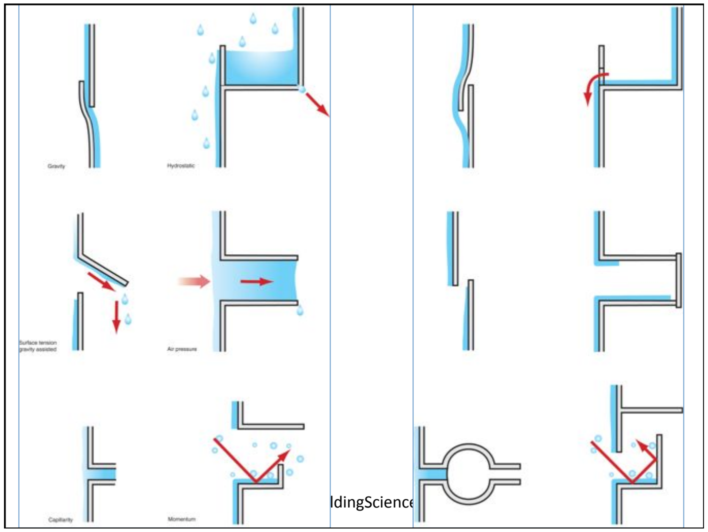
Figure 6.9– Siding WA-15 : Stage 7 - Water entry under static pressure differential through deficiency above vent duct

IRC/MEWS

Penetration Forces Summary

- Gravity is a large force
  - 1000 Pa per 100 mm
  - Drainage relieves and redirects this pressure
- Capillarity *can be* a large force
  - >750 Pa for 0.1 mm crack (important)
  - < 10 Pa for >3 mm crack (i.e.unimportant)
- Air pressure is usually a small force
  - Typically 10 to 100 Pa
  - 1 *second* in 10 years: > 1000 Pa

100



Enclosure Strategies

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Rain Control

- Next to structure, the most important, fundamental requirement
- Source of many serious building problems
- Major impact on durability
- Low-energy buildings & rain
  - Different enclosure assemblies
  - Reduced drying ability= need for better control!

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Enclosure Wall Strategies

- Some water is likely on the wall
- Water can penetrate in many ways

Once rain is on the wall …

- **Drainage**
- **Exclusion**
- **Storage**

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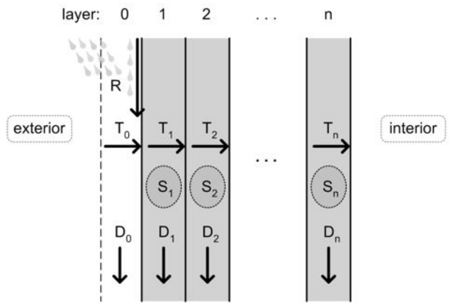
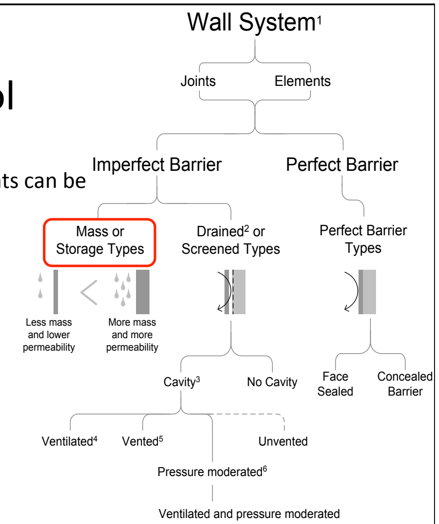
Rain Control Theory



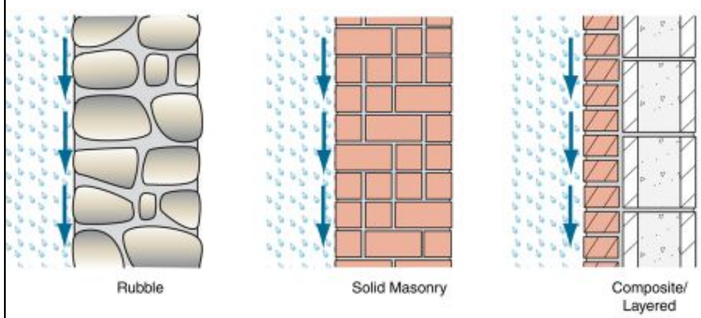
R = driving rain deposition and drainage from above
D = drainage (or shedding on outside layer)
S = storage: capillary absorption + surface tension
T = transmission

Rain Control

- Elements and joints can be different

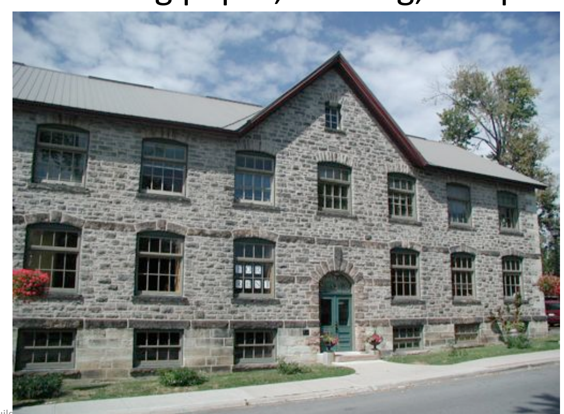


Mass/Storage/Reservoir Walls

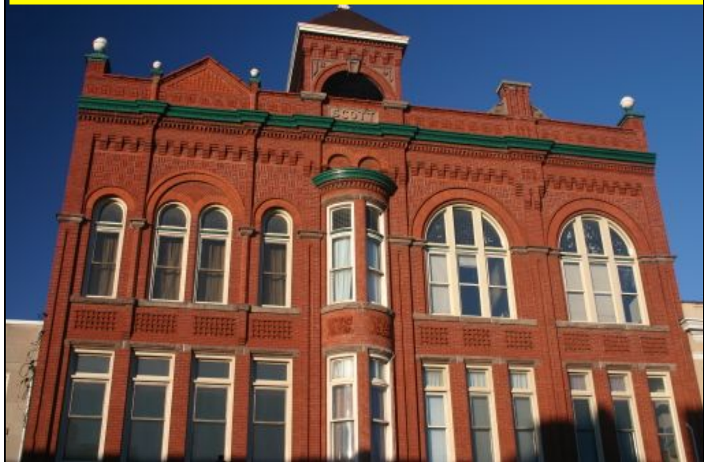


John Straube

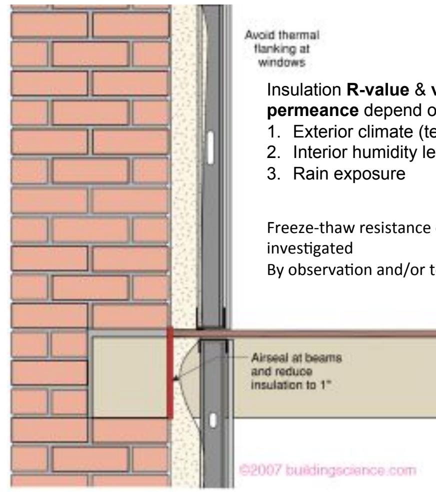
No building paper, flashing, weepholes



Surface features such as Overhangs, Drips, etc are important for mass walls



Rain Control 109



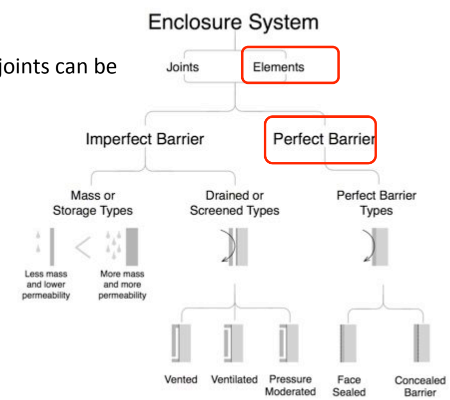
Insulation **R-value** & **vapor permeance** depend on:

1. Exterior climate (temp / drying)
2. Interior humidity levels
3. Rain exposure

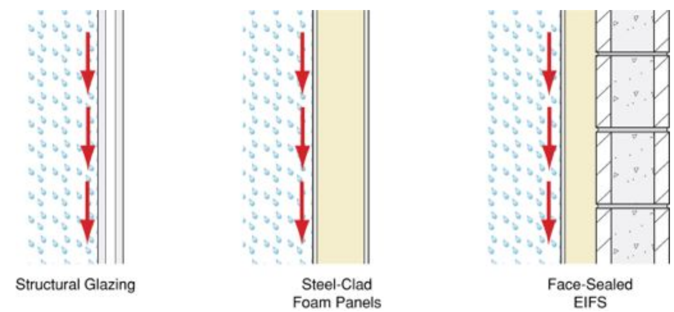
Freeze-thaw resistance of brick should be investigated
By observation and/or testing

Categorization

- Elements and joints can be different



Perfect Barrier / Face Sealed



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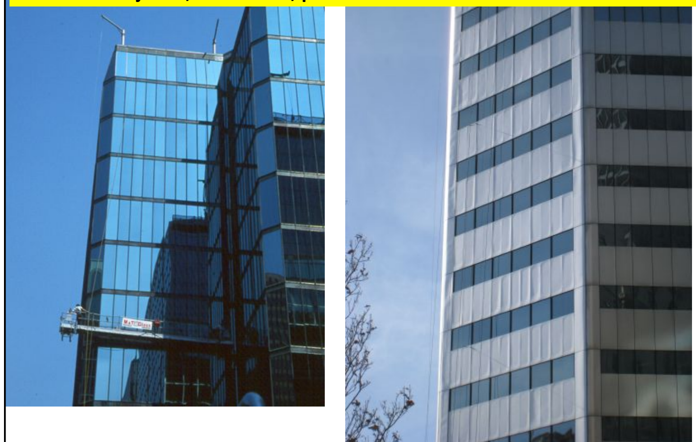
It is all about joints, transitions, penetrations



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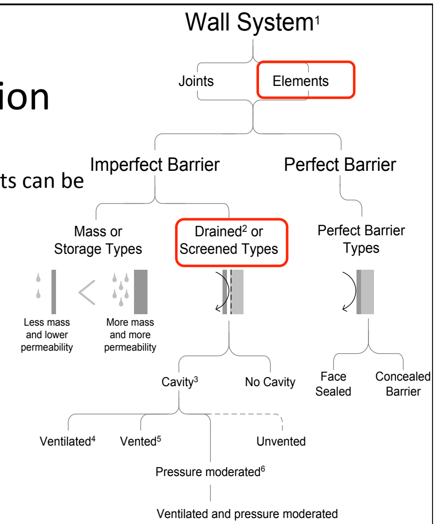
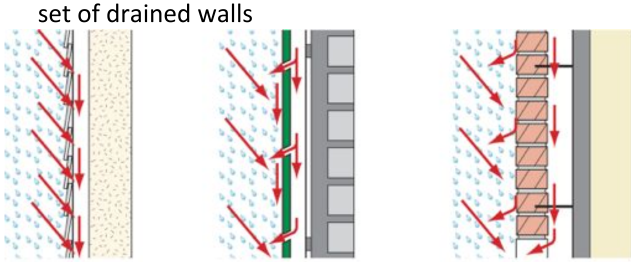
Categorization

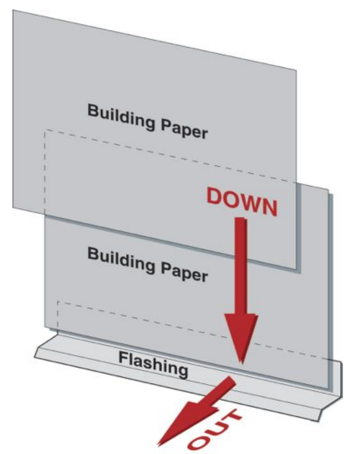
- Elements and joints can be different



Drained Walls

- “Pressure Equalized Rainscreen” are a fictional sub-set of drained walls





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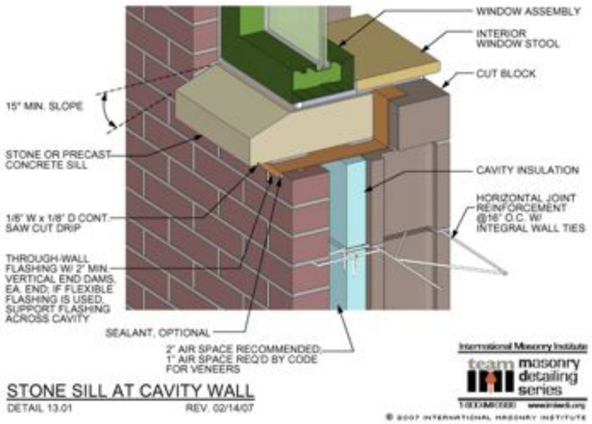
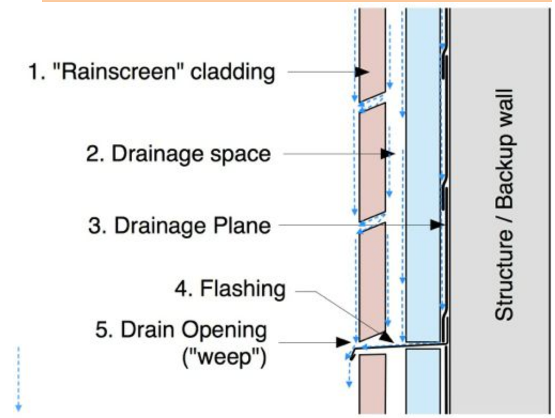
No Drainage plane!



Requirements for a Drained Enclosure



How big should gap be?

- Big question!
- For Drainage
  - only a small gap needed
  - E.g. 1/32", DrainWrap, two sheets building paper
- For Ventilation
  - Larger gaps, likely ¼ to ¾" (6-20 mm)
  - Vent openings important
  - How much ventilation do you need?

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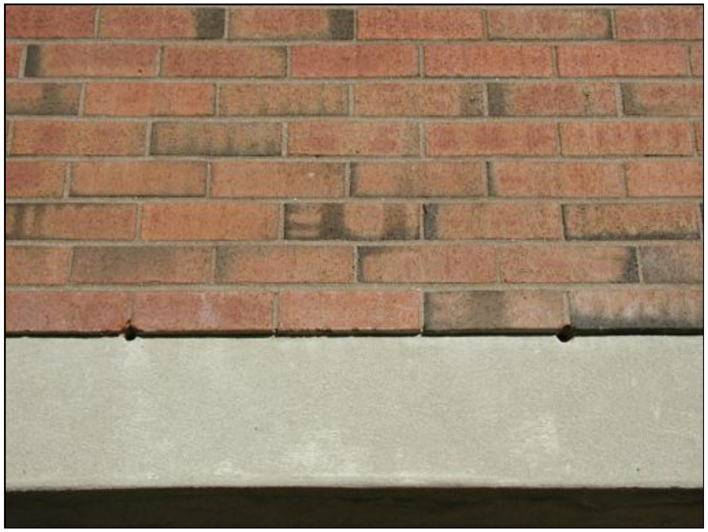
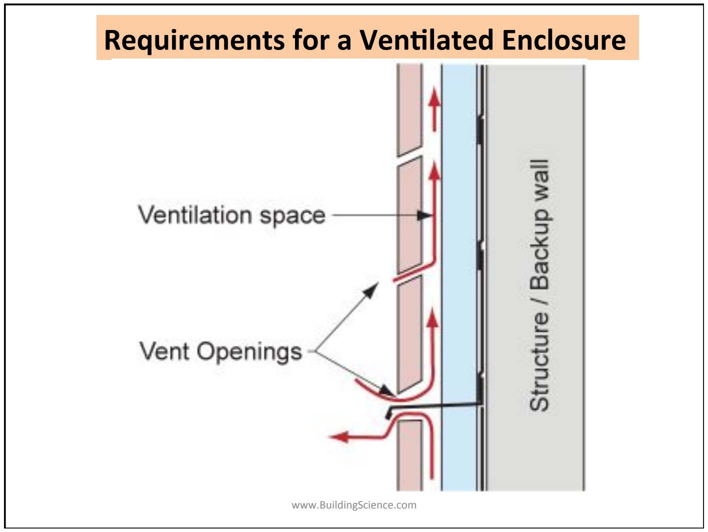
Weepholes weeping


Water weeping out at foundation level




Requirements for a Ventilated Enclosure
Ventilation space
Vent Openings
Structure / Backup wall
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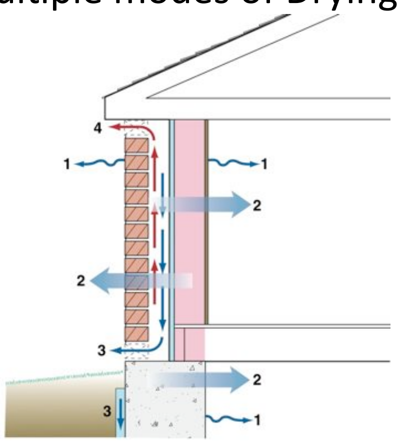
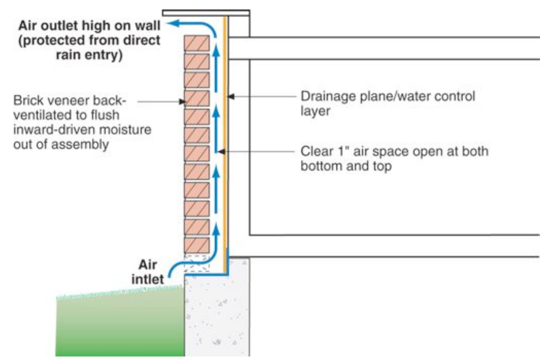
How much Ventilation do you need

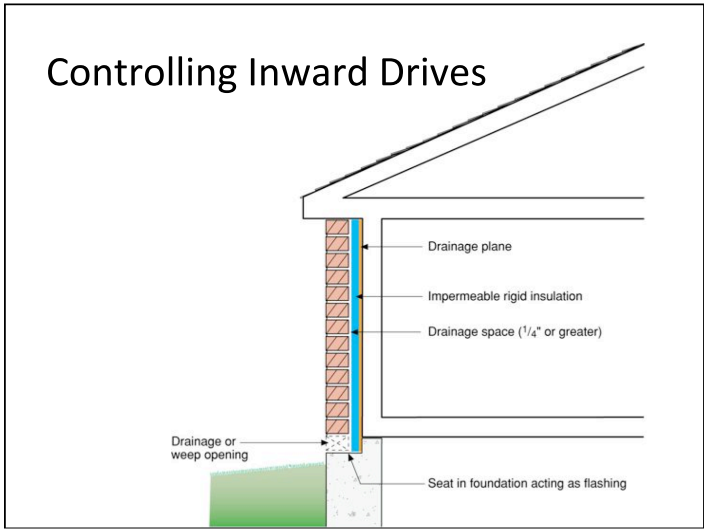
- Are you drying the cladding back?
- Are you drying the wall sheathing?
- Are you controlling inward vapor drives?
- Are materials adjoining the ventilation cavity moisture sensitive?

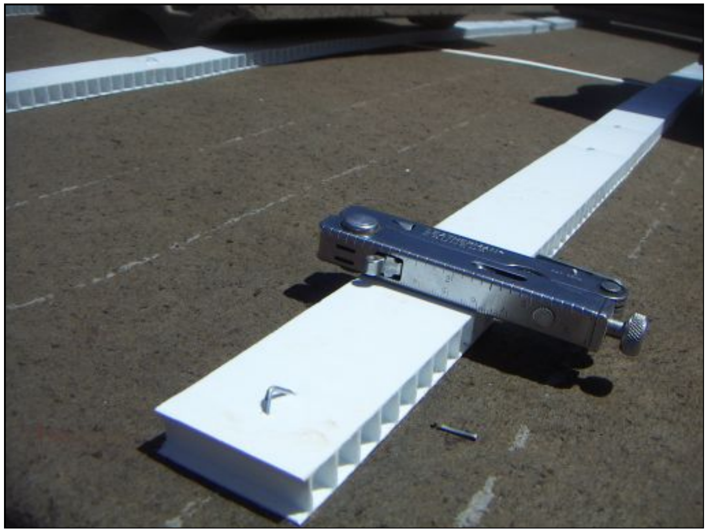
Multiple modes of Drying



Controlling Inward Drives




Controlling Inward Drives
Drainage plane
Impermeable rigid insulation
Drainage space (1/4" or greater)
Drainage or weep opening
Seat in foundation acting as flashing



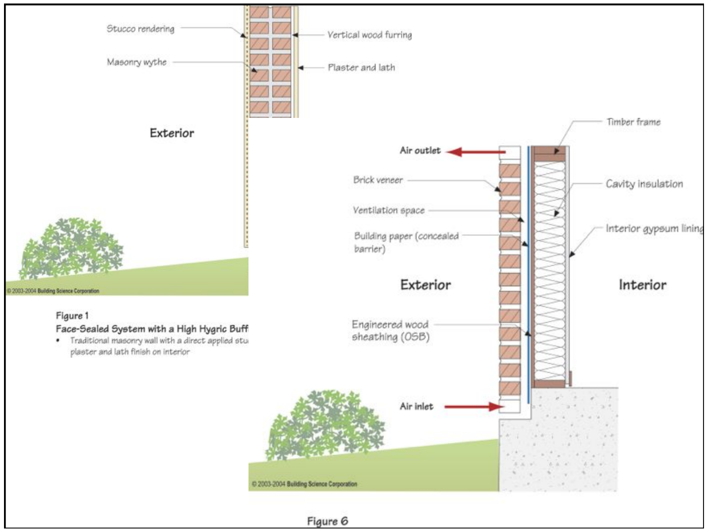

Stucco rendering
Masonry wythe
Vertical wood furring
Plaster and lath
Exterior
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Figure 1
Face-Sealed System with a High Hygric Buff
Traditional masonry wall with a direct applied stu
plaster and lath finish on interior
Timber frame
Air outlet
Brick veneer
Ventilation space
Building paper (concealed barrier)
Cavity insulation
Interior gypsum lining
Exterior
Interior
Engineered wood sheathing (OSB)
Air inlet
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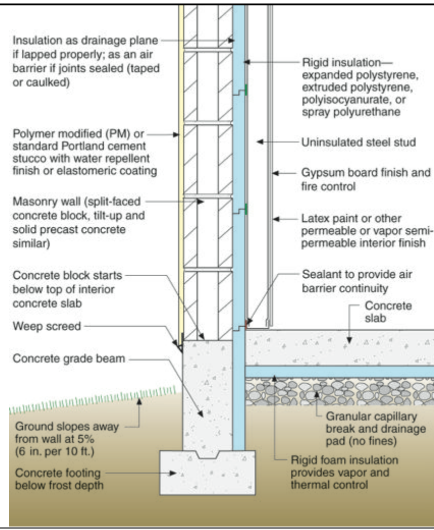
Figure 6



Air-Water-Vapor

- Often thin layers
- *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

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Air-Water Control Layers

Sloped and complex surfaces demand very high performance. LAPPING very Important

Non-adhered, vapor permeable =modest performance

Supported **flexible membrane is better**

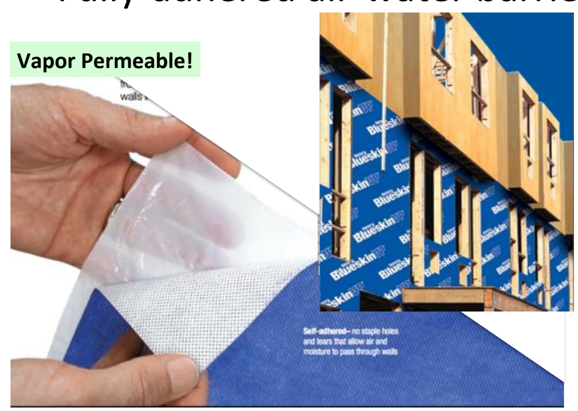
Fluid-applied products avoids laps

Transitions

- Air & water & vapor transition membranes

Fully-adhered air-water barrier

Vapor Permeable!



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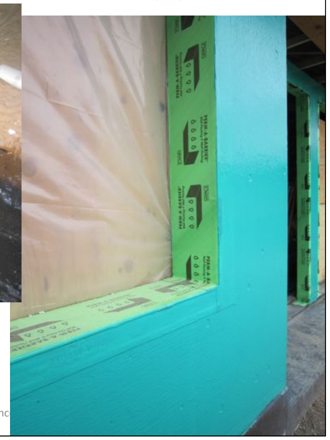
Mixed membrane + fluid-applied

Often use membranes for transitions

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Spray/Trowel Applied Air/water

- Semi-permeable


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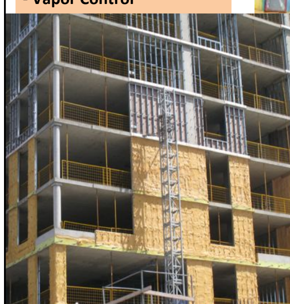
Closed-cell spray polyurethane foam: ccSPF
-Rain control
-Air Control
-Thermal Control
- Vapor Control




Which Strategy to Use?

- Depends on Exposure to Rain
- Which depends on
  - Climate
  - Height of building
  - Orientation
  - Shape
  - Surface Features
  - Complexity

John Straube

•**Rain control strategies are often mixed**

•**Should be done with intent and consideration of exposure**

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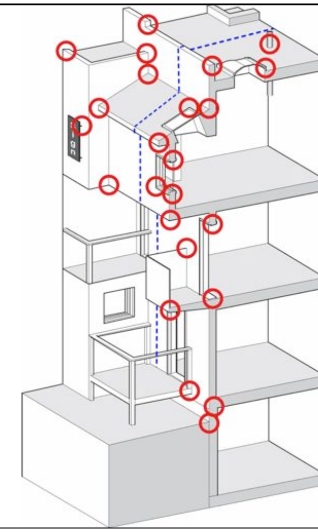
Details required at
1. Changes in plane
2. Changes in material
3. Changes in system / trade

Thus penetration, windows, rails, signs etc.



Examples

- Roofs and basements also are categorized as mass, perfect barrier and drained

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