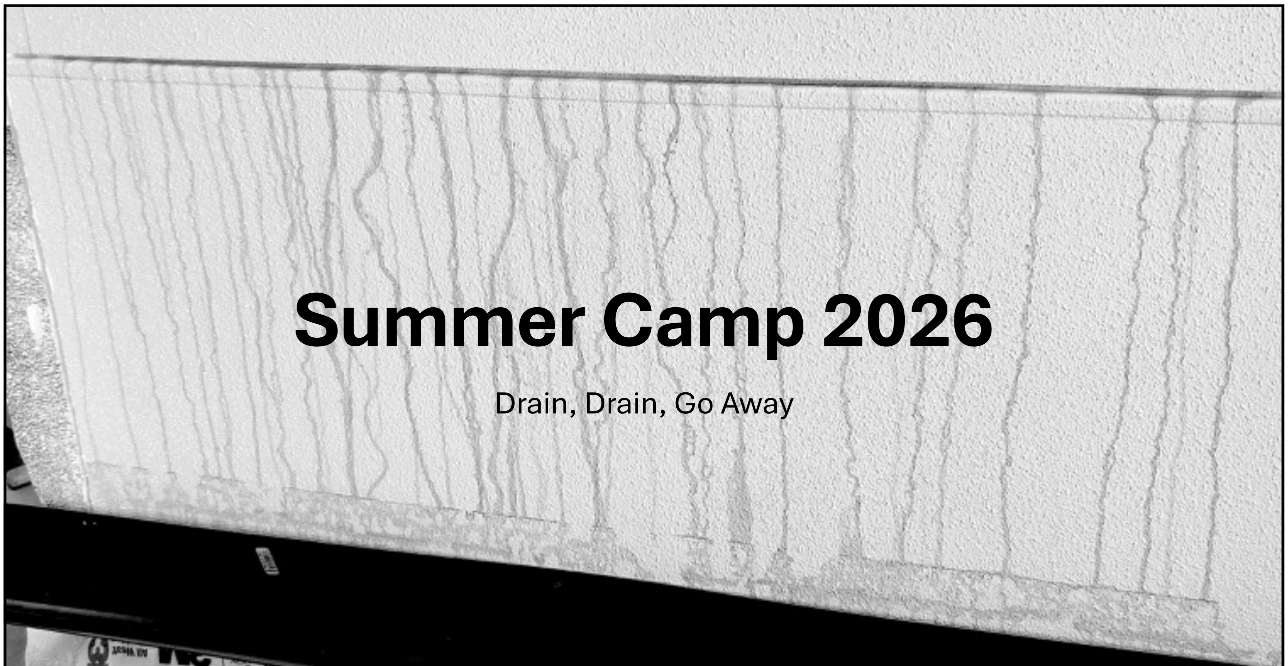

Summer Camp 2026

Drain, Drain, Go Away

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Agenda Description

- Drainage has gone from being largely ignored in historical documents to forming the core performance requirement of many systems. Drainage behind cladding, within curtainwall framing, along hidden flashing, through weep holes, down precast panel joints, and within foundation drainpipes is now required for the successful performance of many parts of modern buildings. This presentation will examine how much drainage can be expected in each of these systems based on physical measurements and theoretical calculations. Different drainage strategies for different building components will be assessed, recommendations provided, and risk factors identified.

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Joe's Drainage

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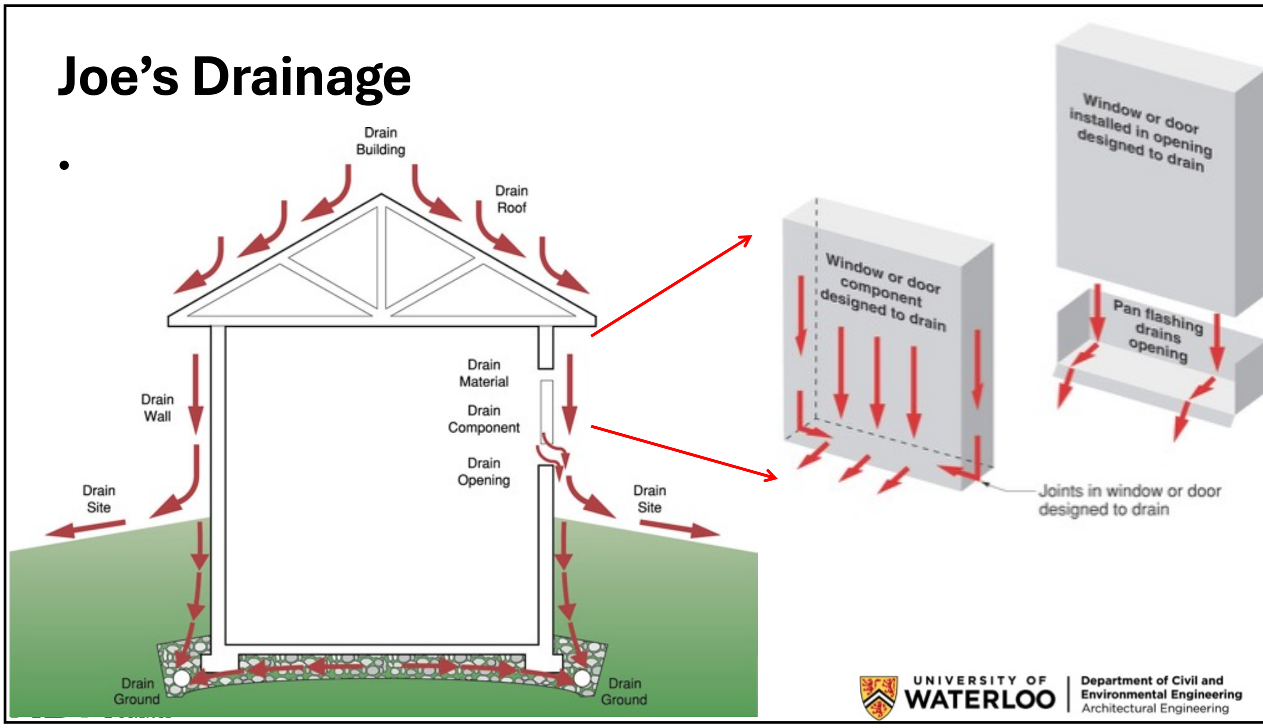

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How much rain do we need to drain?

- Depends on how much:
  1. rain falls
  2. rain is deposited on enclosure (wind driven rain + exposure)
  3. deposition may be dispersed or concentrated
  4. penetrates the cladding (say 1%)
  5. that reaches the WRB, or joint, or flaw (say 1 to many %)

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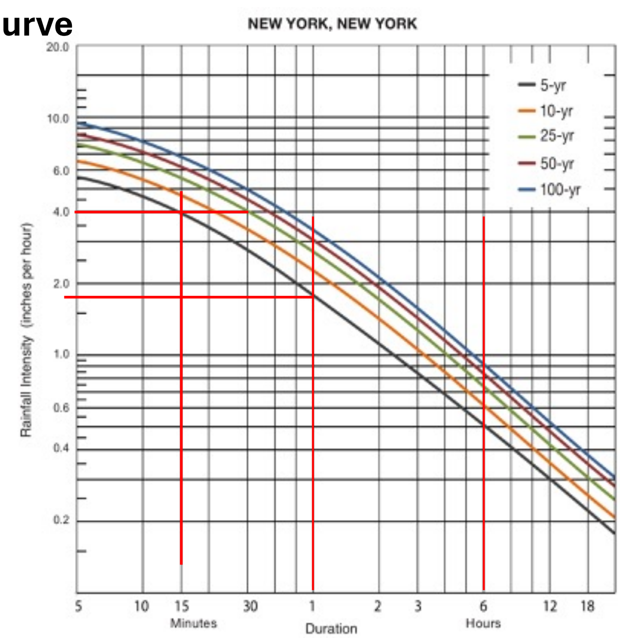
Drainage

- Surface drainage
  - Walls
  - roofs
- Internal drainage
  - Walls
  - Windows
  - Joints

Rainfall (on horizontal surface)

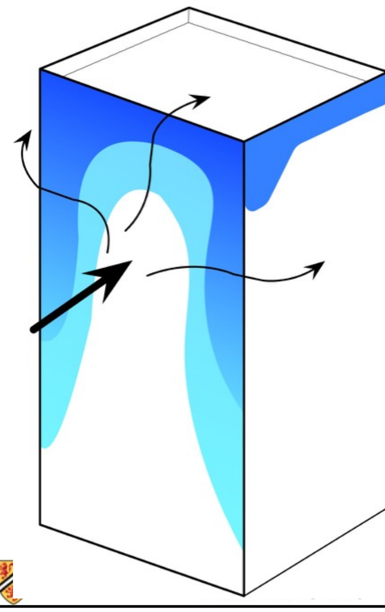
Intensity - Duration - Frequency Curve

- Profile varies with location
- Available for stormwater design
- All climates show *decreasing intensity with duration*
- Short intense bursts
- Long, steady rainfall
- E.g. NYC
  - 4”/hr for 15 minutes (1-in-5 yr)
  - 1.75”/hr for 1 hr
  - 0.5”/hr for 6 hrs



Rain Deposition

- Rain deposition on walls is predictable … approximately
- Wind pushes sideways, rain fall drops down, aerodynamics influences flow
- Upper parts and corners see the most water
- Deposition rate *varies directly with windspeed*
    - Double wind speed, double deposition
    - Exposed buildings and taller buildings have higher wind speeds, ergo, more rain deposition



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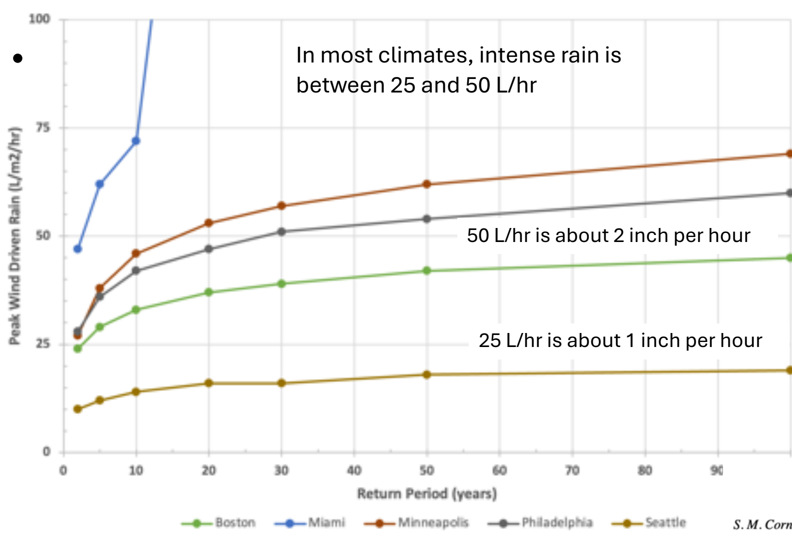
Rain Deposition from Climate records

- In most climates, intense rain is between 25 and 50 L/hr



1% leakage is 8.3 mL/<u>min</u>/m²

1% leakage is 250 mL/<u>hr</u>/m²

Journal of ASTM International, Vol. 6, No. 2
Paper ID JAI101210
Available online at www.astm.org

*S. M. Cornick[1] * and M. A. Lacasse[1]*

An Investigation of Climate Loads on Building Façades for Selected Locations in the United States

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Surface Drainage aka "Run-Off"

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Wall Surface Drainage

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Concentration

- Very situational
- The reason we like water shedding flashing
  - Both on surface (cornices, sills)
  - And with drainage gap

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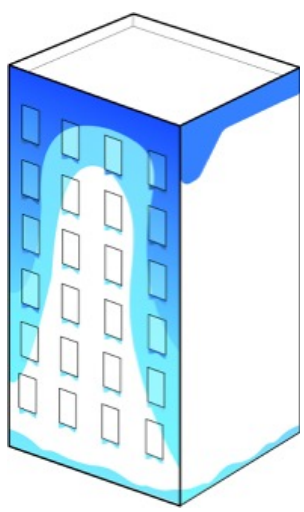
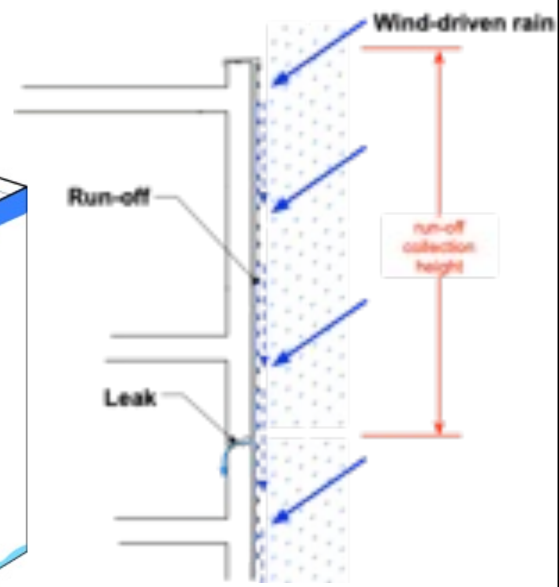
Accumulation

- Surface drainage can build up
  ... or it can shed off





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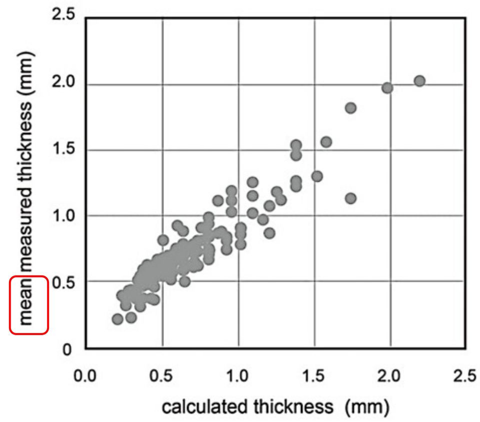
Surface drainage forms films in theory

- More flow volume (Q) means thicker & faster films
- This was already done by Nusselt long ago!
- $thickness = \sqrt[3]{\left(\frac{3 \cdot Q \cdot \mu}{\rho \cdot g \cdot \sin \alpha}\right)}$
- $speed = \sqrt[3]{\frac{\rho \cdot g \cdot Q^2 \sin \alpha}{3\ \mu}}$
- water density (**ρ**) and viscosity (μ) are important



W. Nusselt. “Die Oberflachenkondensation des Wasserdamphes”, *Zeitscrift des vereines Deutschem Ingenieure* 60 (3) (1916) 541–54

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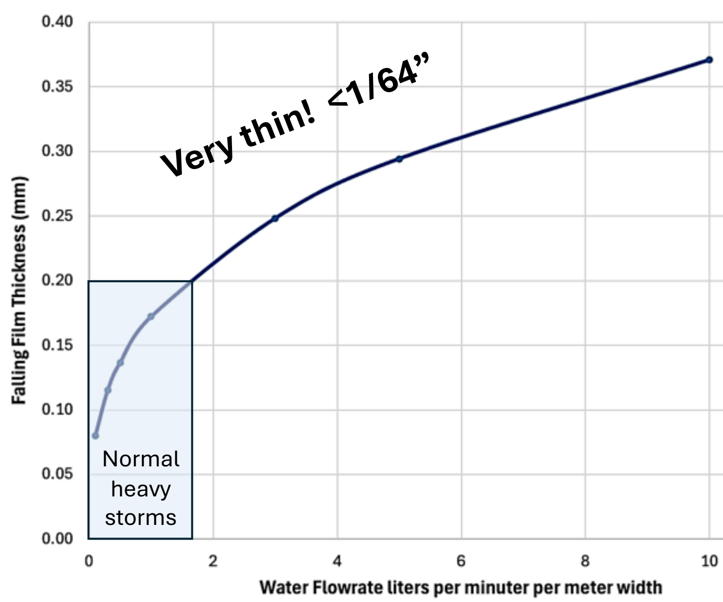
What kind of vertical films can form in theory?



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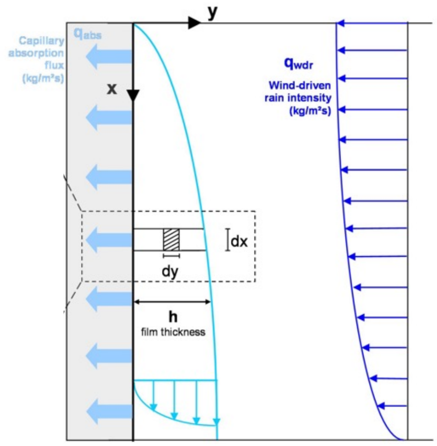
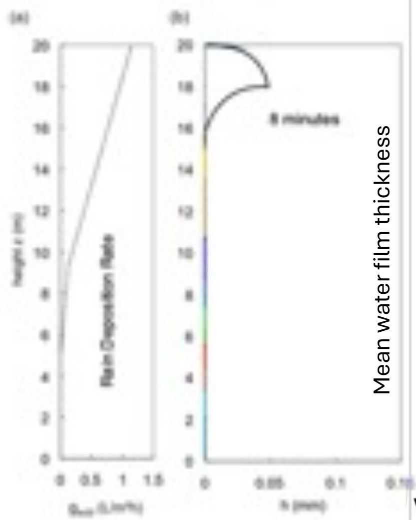
Surface Run-off with absorptive claddings

- Rain deposition varies over height of brick veneer





Blocken B, Carmeliet J. 2012. "A simplified numerical model for rainwater runoff on building facades: possibilities and limitations". *Build Environ* 53, pp. 59-73.

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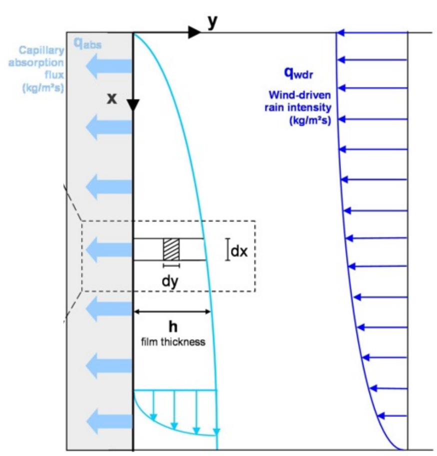
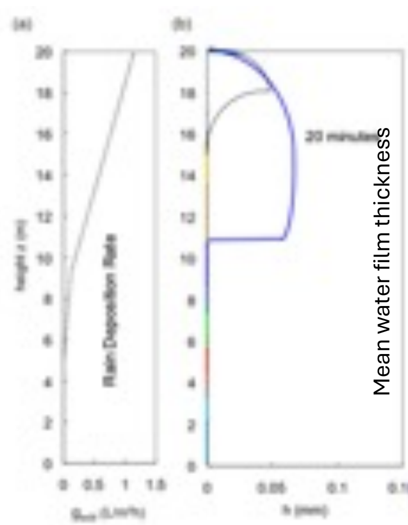
Surface Run-off with absorptive claddings

- Rain deposition varies over height of brick veneer





Blocken B, Carmeliet J. 2012. "A simplified numerical model for rainwater runoff on building facades: possibilities and limitations". *Build Environ* 53, pp. 59-73.

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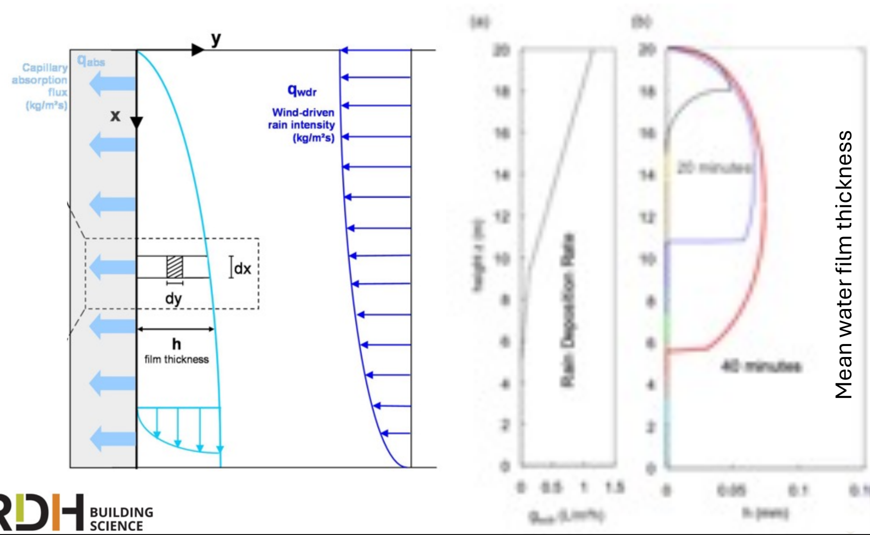
Surface Run-off with absorptive claddings

- Rain deposition varies over height of brick veneer



Blocken B, Carmeliet J. 2012. "A simplified numerical model for rainwater runoff on building facades: possibilities and limitations". *Build Environ* 53, pp. 59-73.

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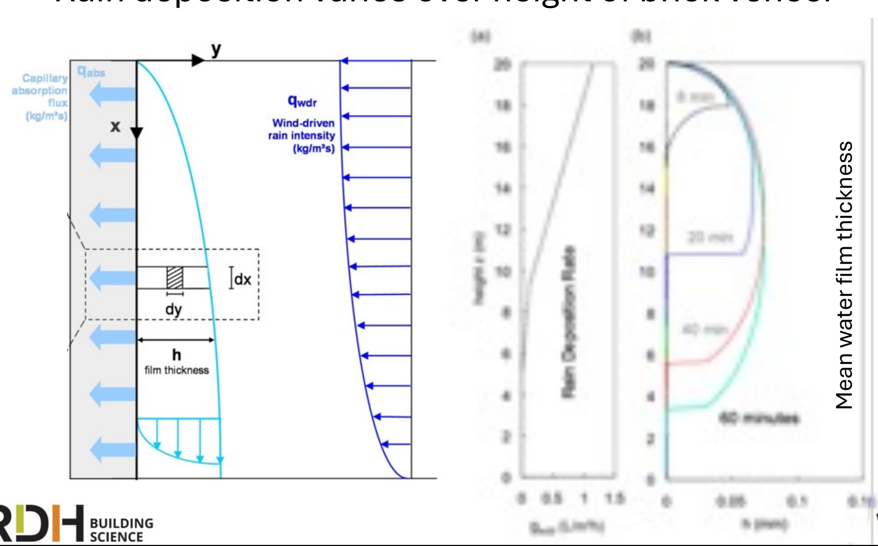
17

Surface Run-off with absorptive claddings

- Rain deposition varies over height of brick veneer



Blocken B, Carmeliet J. 2012. "A simplified numerical model for rainwater runoff on building facades: possibilities and limitations". *Build Environ* 53, pp. 59-73.

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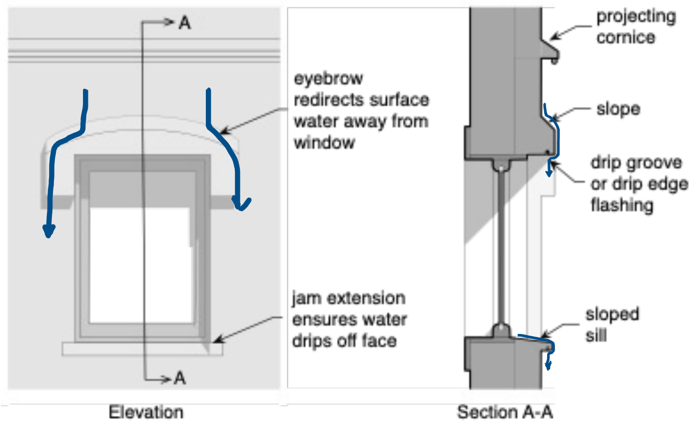
Shedding

- Façade details matter



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Wall Surface Drainage: Run-off vs Shedding

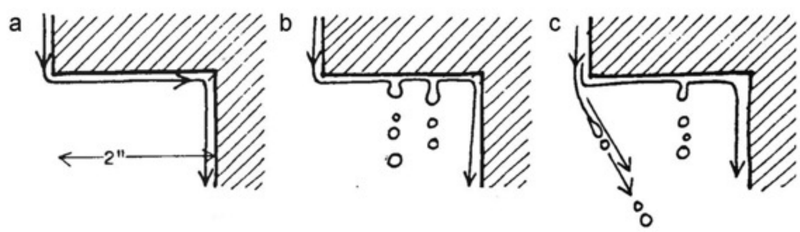

Figure 11. Vertical cross-sections with indication of surface tension effects for (a) low, (b) moderate and (c) high runoff flow rate (from [186]).

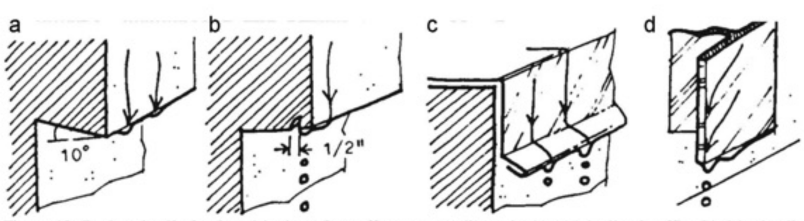

Figure 12. Design details for free dripping of runoff water at a discontinuity: (a) inclined soffit; (b) drip detail; (c) flashing; (d) T-mullion (from [186]).

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Measured Drip effectiveness

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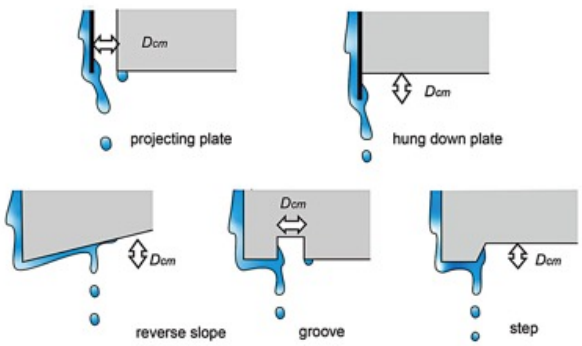

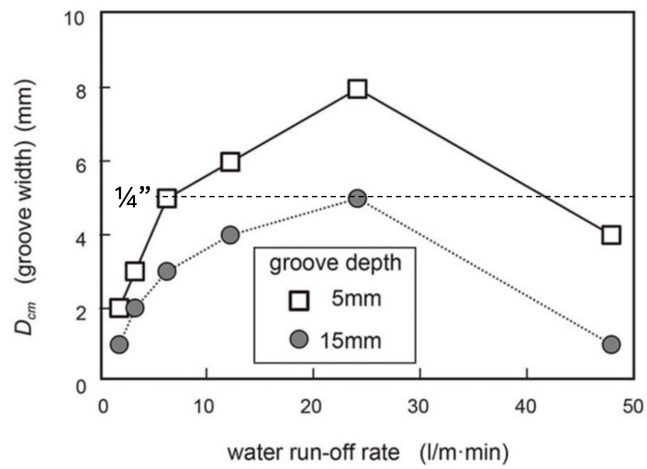

Ishikawa, H., 2023. *Rainwater Control in Buildings.* Academic Research Publication, Japan.

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Drip Edge Issues

Toronto Education Building
Freeze-thaw damage

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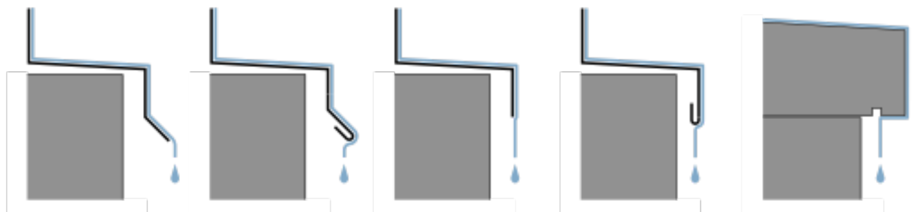
Research Scope

- Five different profiles
  - Metal gauge: 12 (thick) or 20 (thin)
  - Overhang Distance: (13, 20mm, 45mm) ½”, ¾, 1-3/4”
  - One Stone w/groove
  - Run-off rate 0.2 L/h/m (1 Gal/h/ft)
- Goals:
  - Measure Vertical distribution quantitatively
  - Observe Horizontal distribution qualitatively



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Water set-up

- Run-off rate:
  0.2 L/h/m (1 Gal/h/ft)
- Replaceable drip

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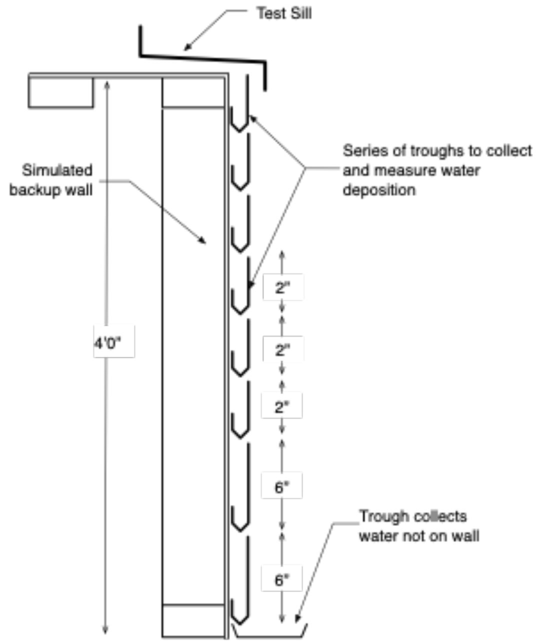

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¾” and 1-3/4” drip projections

		12 gauge (thick)								12 gauge (thick)							
		90° hemmed				90° (no hem)				45° hemmed kickout				45° kickout (no hem)			
		20 mm		45 mm		20 mm		45 mm		20 mm		45 mm		20 mm		45 mm	
	Trough	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
2”	1	13.1	29.0	0.0	0.0	0.2	0	0	0	15.8	10.5	0.0	0.1	0.1	0	0	0
2”	2	11.6	4.0	11.0	32.0	12.2	1.1	0.2	0	16.4	12.4	0.0	0.2	1.3	8.8	0	0
2”	3	0.4	0.1	48.0	36.0	5.9	4.3	0.1	0	2.5	0.5	0.7	0.9	0.8	3.2	0	0
2”	4	0.1	0.0	24.0	7.0	1.9	5.9	0.2	0	0.6	0.1	4.1	9.9	0.8	0.9	0.2	0
2”	5	0.0	0.0	4.0	0.0	0.6	1	0	0.2	0.6	0.2	2.3	3.2	0.7	1	0.5	0.1
6”	6	0.0	0.0	2.0	0.0	0.3	0.3	0.1	0.6	2.6	3.6	5.0	5.0	5.7	5.6	1.7	6.4
6”	7	0.1	0.0	1.0	0.0	0.5	0.3	0.3	1.5	0.9	0.7	0.4	1.1	1.9	1.5	1.6	2.6
6”	8	0.4	0.0	0.0	0.0	0.9	1	2.2	4.3	0.7	0.1	2.0	0.3	0.7	0.6	9.9	9.2
	Total Collected	**25.7**	**33.2**	**90.0**	**76.0**	**22.3**	**14**	**3.1**	**6.6**	**40.1**	**28.2**	**14.5**	**20.8**	**12.1**	**21.6**	**13.8**	**18.3**
	Total Shed	**74.3**	**66.8**	**10**	**24**	**77.7**	**86**	**96.9**	**93.4**	**59.9**	**71.8**	**85.5**	**79.2**	**87.9**	**78.4**	**86.2**	**81.7**

48.0 - red shading with white text indicates a single trough collection greater than 10% of total water applied

95.1 - green shading with black text indicates a total water shed greater than 90% of the total water applied

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Drip Test Summary

Drip edge Profile	Overhang Distance (mm)	Proportion Shed (%)
Vertical hemmed	13	4
	25	27
	45	22
Sharp-edge 45 deg	20	70
	25	89
	45	88
45 deg hemmed	30	62
	45	84

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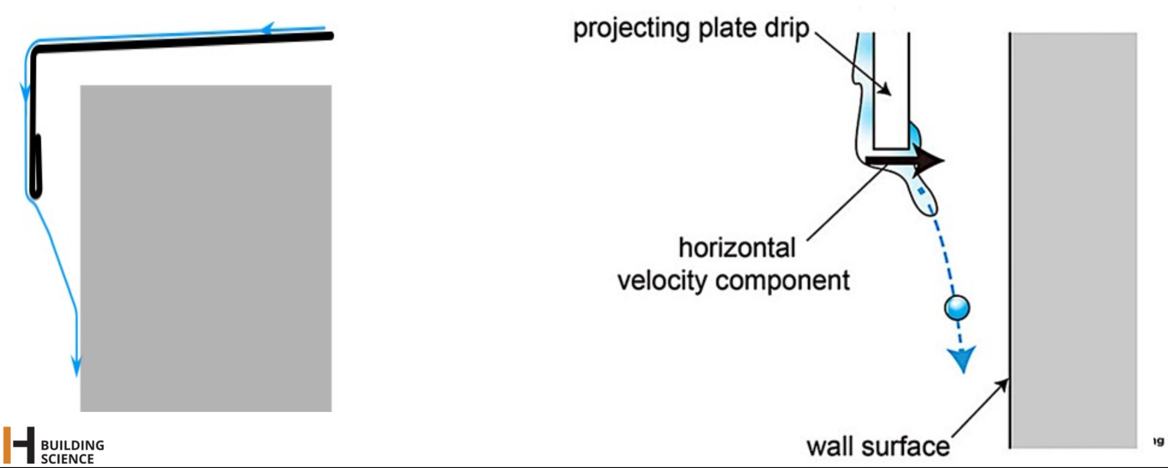
Drip Edge profiles

- Shape changes drainage path
- Flow rate can change behavior



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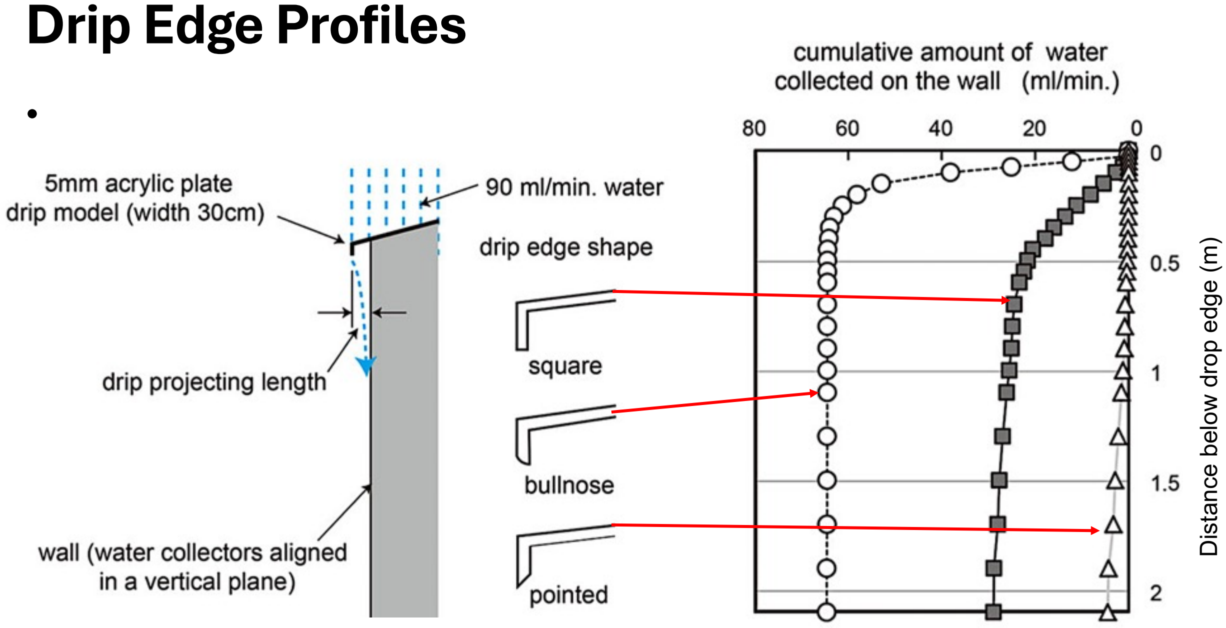
Drip Edge Profiles

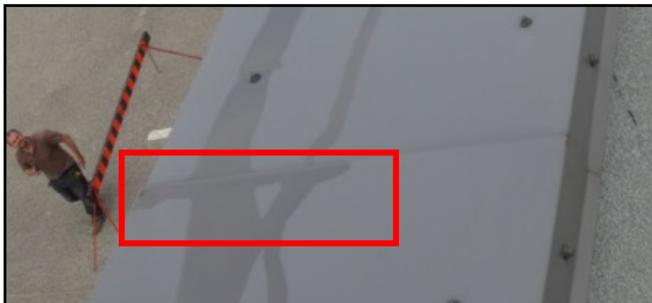
-

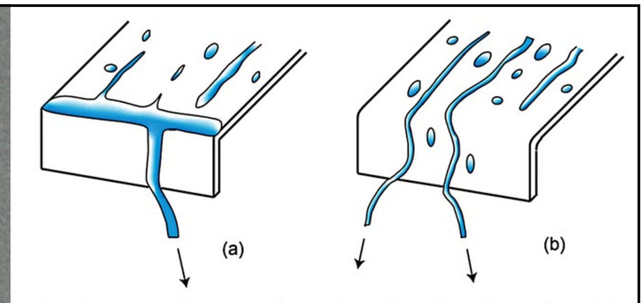


Ishikawa, H., 2023. *Rainwater Control in Buildings*. Academic Research Publication, Japan.

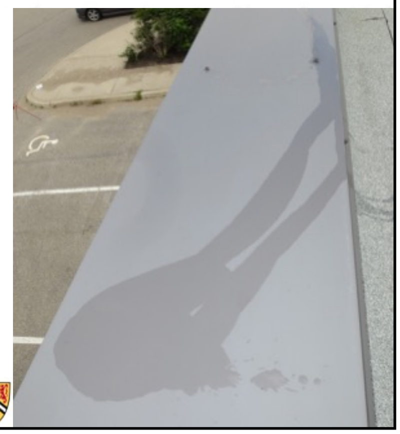
30 mm (1-1/4”) drip projection

30





- Water flow is inadvertently directed by sheet metal bends / joints



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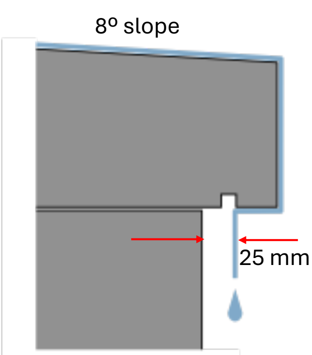
Stone sill

- 25 mm (1”)



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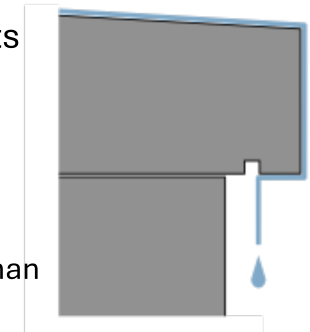
Limestone Sill Results

- Water distributed laterally more, formed fewer rivulets
- 100% of water was shed, no water was measured in any trough
    - Better than the best 45 mm metal drop
- Horizontal distribution appeared to be improved
    - Many more drip locations on the bottom of the stone sill than on the metal sills, water falls slower, not as streams



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Internal Drainage "Planes"

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Historically, solid walls, no internal drainage

- Water works are on the outside
- Exterior rain leaders, significant surface shedding features, massive storage ... but no drainage

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Modern Drained

- Drainage gap behind cladding
- Drainage of joint between windows and walls
- Drainage of window frames

- No surface shedding
- Limited storage
- Internal leaders

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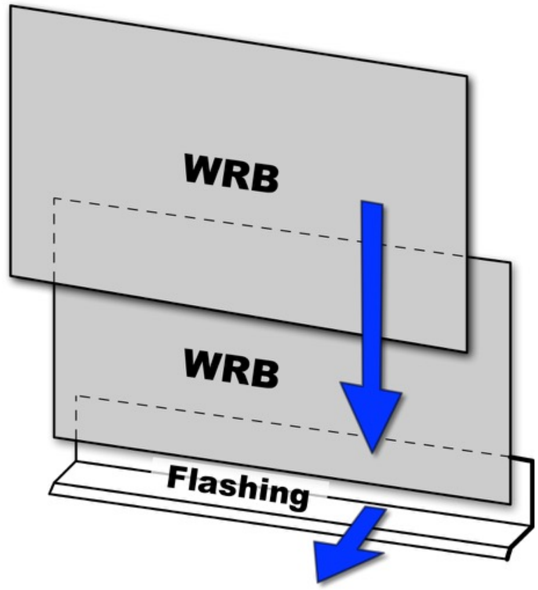
Simple Wall Drainage

- ”drain the rain on the plane”
- **W**ater **R**esistant **B**arrier
- Not “weather” and not “proof”



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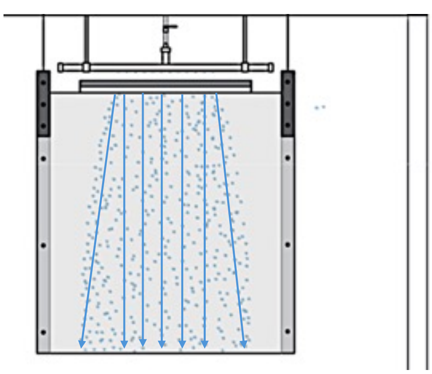
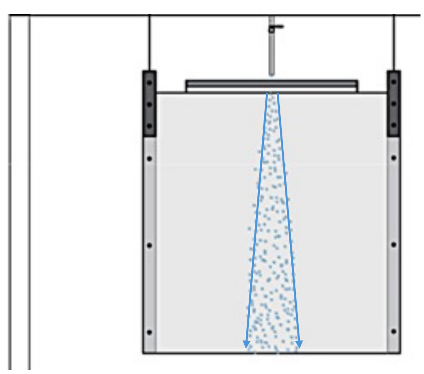
Leaks: Point, line, or area source of water?

- Many real-world leaks are <u>point</u> sources
- Most standard tests are <u>area</u> sprays



Line Source



Point Source

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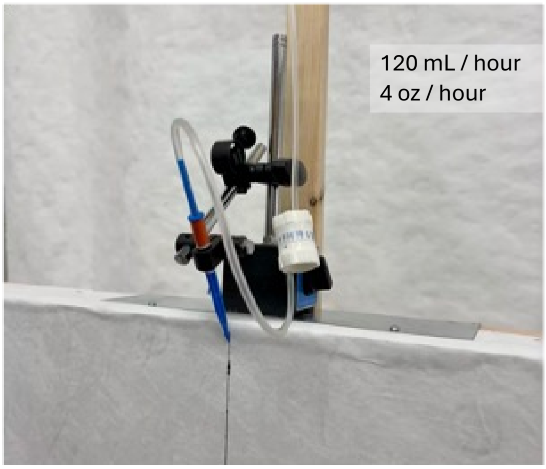
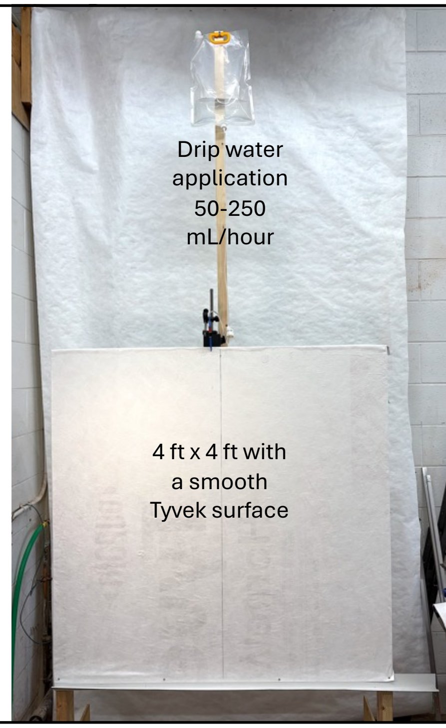
RDH Experiment: Actual thickness

- Started with droplets
- Very slow rate (realistic?)





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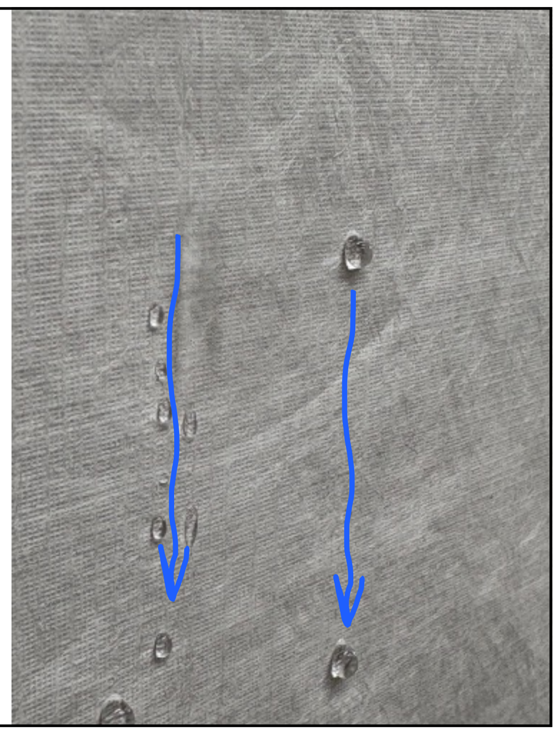
Droplets and Rivulets

- Water droplets ran almost directly downward
- A narrow fan (5 degree)
- Wrinkles and laps were not tested but probably will move drainage sideways
  - Future work



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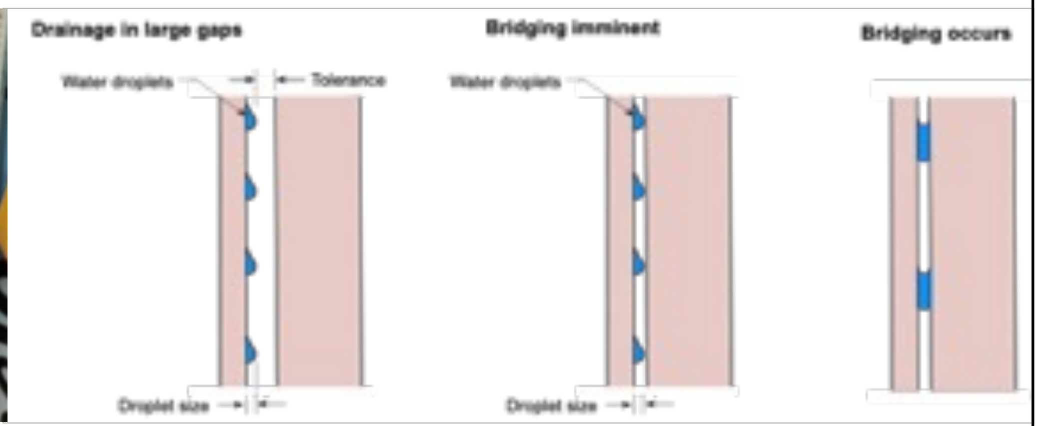
Droplet size & bridging

Droplets measured < 1/8"



When does bridging start?

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Research

11th Canadian Conference on Building Science and Technology
Banff, Alberta, 2007

The Role of Small Gaps Behind Wall Claddings on Drainage and Drying

John Straube, Ph.D.
Civil Engineering Dept & School of Architecture, University of Waterloo
Jonathan Smegal, M.A.Sc.
Building Science Consulting, Waterloo, Ont

Thermal Performance of the Exterior Envelopes of Whole Buildings XIV International Conference, 2019

Water Management in Cladding Systems with Small Drainage Cavities: A Review

Stéphanie Van Linden   Nathan Van Den Bossche

7th International Building Physics Conference, IBPC2018

Drainage and retention of water in small drainage cavities: Experimental assessment

Stéphanie Van Linden[1,*], Michael Lacasse[2] and Nathan Van Den Bossche[1]
[1]Faculty of Engineering and Architecture of Ghent University, Ghent, Belgium
[2]NRC Construction, National Research Council Canada, Ottawa, Canada

Theresa A. Weston[1] and Kimdolyn Boone[1]

A Review of Cladding Drainage Testing, Standards, and Codes

Citation
Weston, T. A. and Boone, K., "A Review of Cladding Drainage Testing, Standards, and Codes," *Exterior Insulation and Finish Systems (EIFS): Performance, Progress, and Innovation, ASTM STP1585*, P. E. Nelson and B. Egan, Eds., ASTM International, West Conshohocken, PA, 2016, pp. 183–196, doi:10.1520/STP158520140116[2]

Drainage and Drying of Small Gaps in Wall Systems

2006

Jonathan Smegal
A thesis
presented to the University of Waterloo
in fulfillment of the

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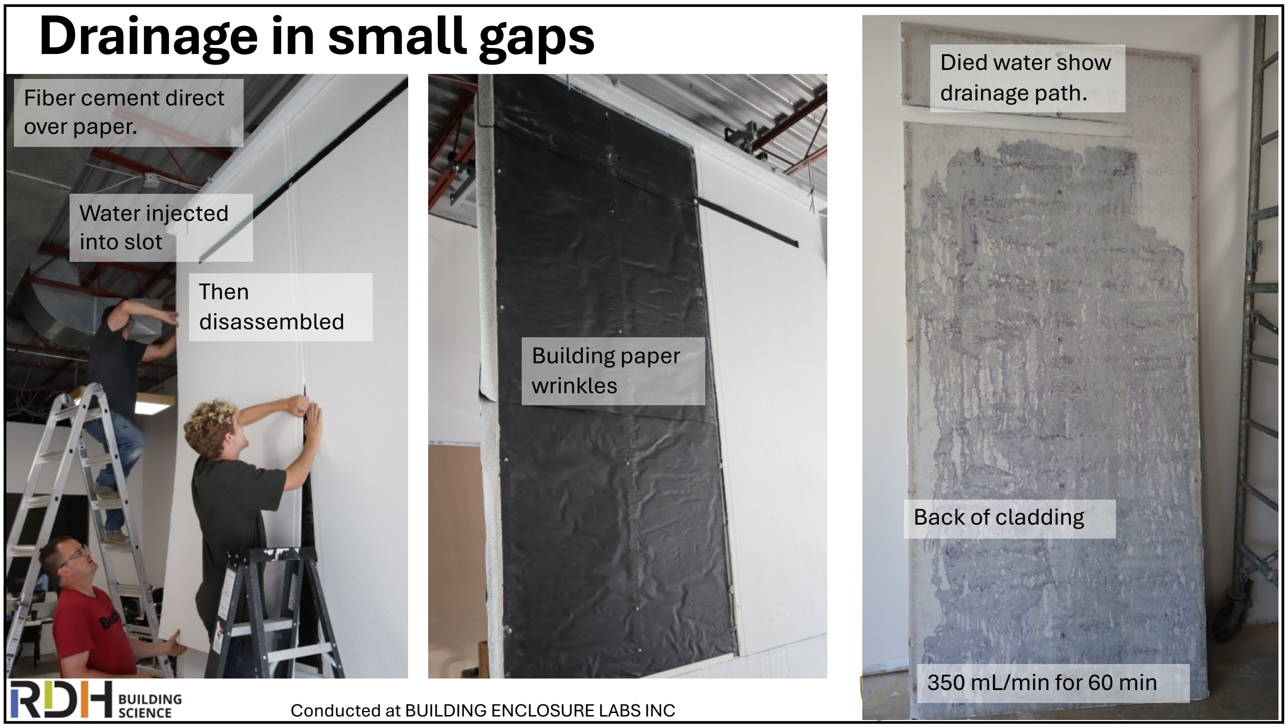
Drainage in small gaps



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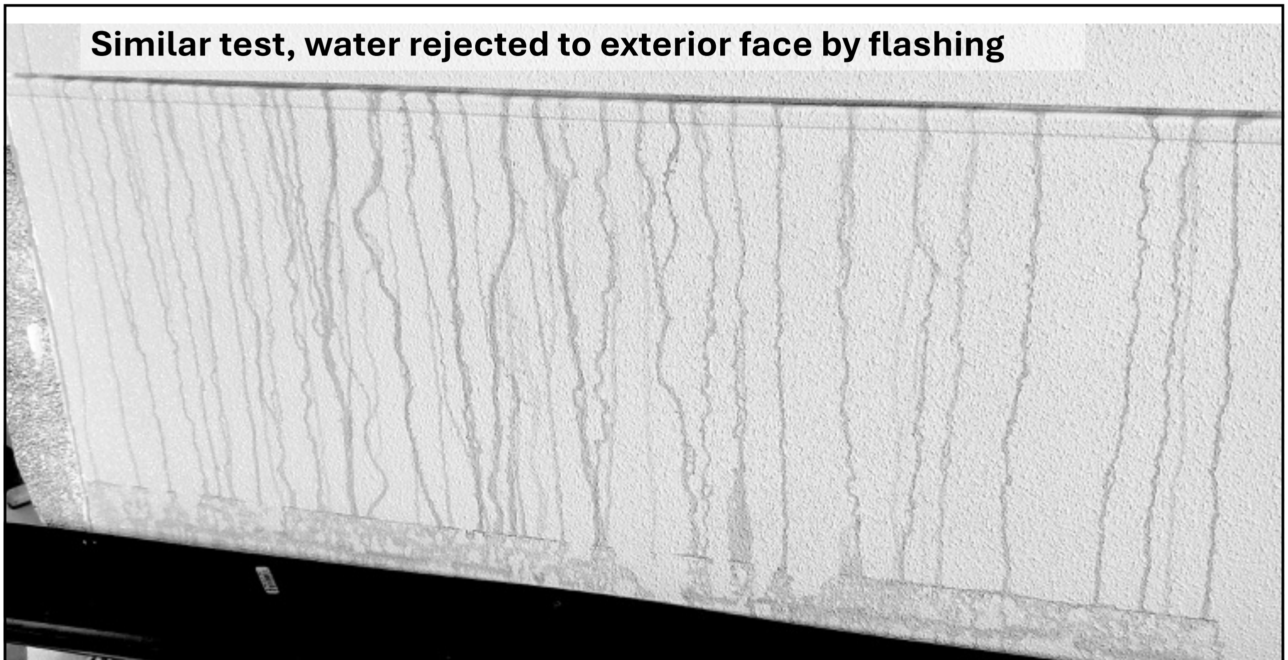
Similar test, water rejected to exterior face by flashing



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Research Conclusions

- Now 20 yrs since Jon Smegal's pioneering work
- Essentially all serious followup research shows meaningful drainage in small gaps
- But…
  - how big does a gap have to be before water crosses the cavity?
  - And when do we care if it does?

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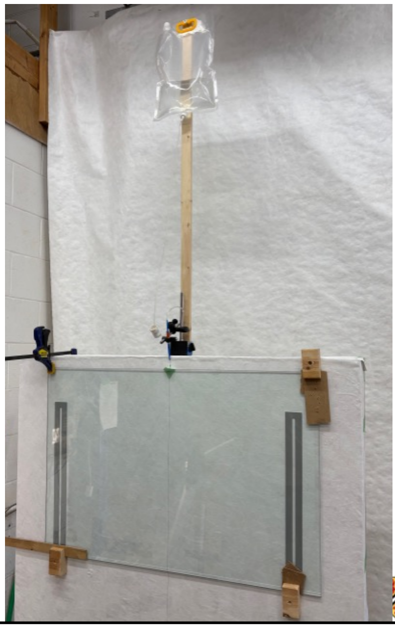
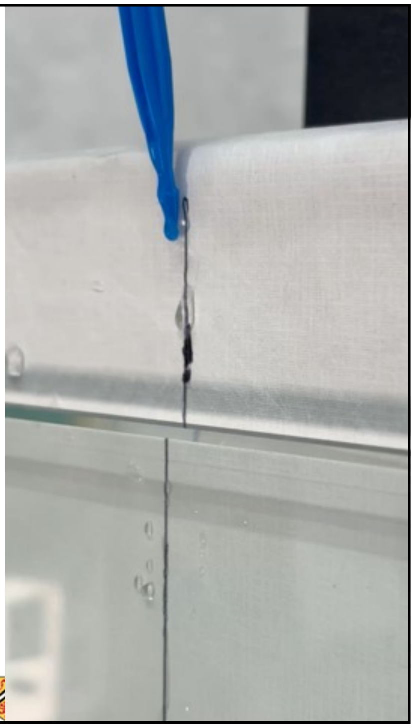
Rain in small gaps

- Used glass cladding
- 3.1 mm (1/8")
- 2.1 mm (5.5/64")

- *Sometimes*, drops crossed at 2.1 mm
- Flow rate had no big effect over range of 50-250 mL/hr





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Multiple-layers

- Lab testing of 4' x 8' wall
- Exterior insulation over WRB
- *Open-jointed* cladding to increase rain leakage through cladding
- Measure drainage at each layer


ROXUL

Drainage Balance Testing and Wall Comparison

July 2014

Available on-line:
https://www.rdh.com/resource/drainage-balance-testing-of-mineral-wool-insulation/

Prepared by

BSCI

Building Science Laboratories | Building Science Consulting Inc.
167 Lexington Court, Unit 5
Waterloo, Ontario
Canada N2J 4R9

Jonathan Smegal, M.A.Sc.
John Straube, PhD, P.Eng

www.buildingsciencelabs.com

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Open-jointed cladding

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Open Rainscreen Drainage Testing

- Open-jointed cladding : 6” clear acrylic with 1/2” open gaps
- ¾” clear air gap
- Exterior insulation:
  - 2” XPS or 3” stone wool

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Testing

- Spray rack used to apply water at 3.4 L/(m^2·min) [5.0 US gal/ft^2·hr]
  - Like ASTM E331 E547 & ASTM E1105
  - Very high rate of wetting
- Wall was weighed during spraying
- Drainage from different layers captured in troughs

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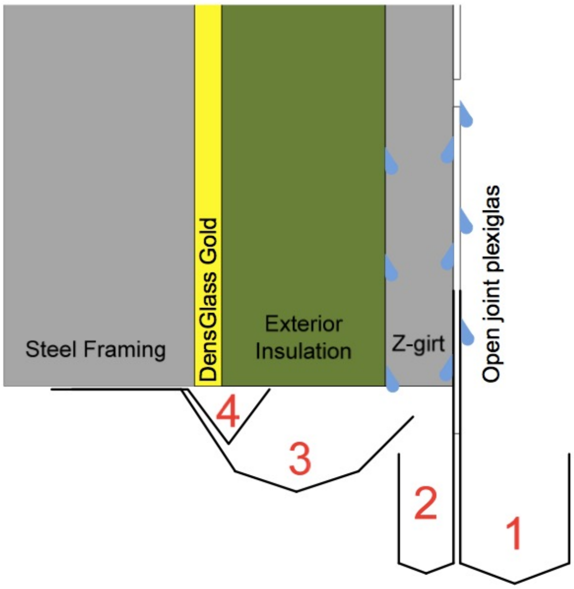
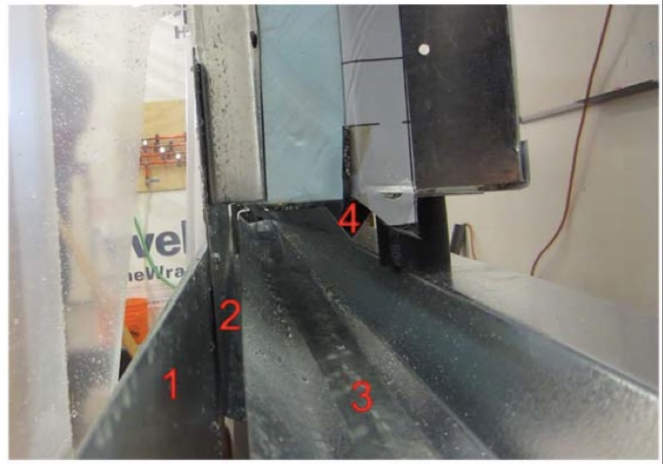
Collection of Drainage at 4 Layers





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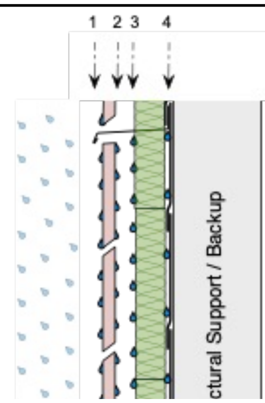
Example Results



- Mineral fibre and foam performed almost the same
- **50-60% drained on front and back of cladding**
- Some water splashed off the front
- Little (<1%) to no water on the WRB (layer 4)!

	1	2	3
Test	Exterior of Cladding	Interior of Cladding	Exterior of Insulation
9	34%	24%	28%
10	31%	21%	28%
11	33%	21%	29%
Average	33%	22%	29%

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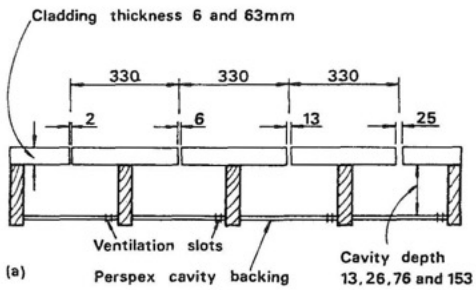
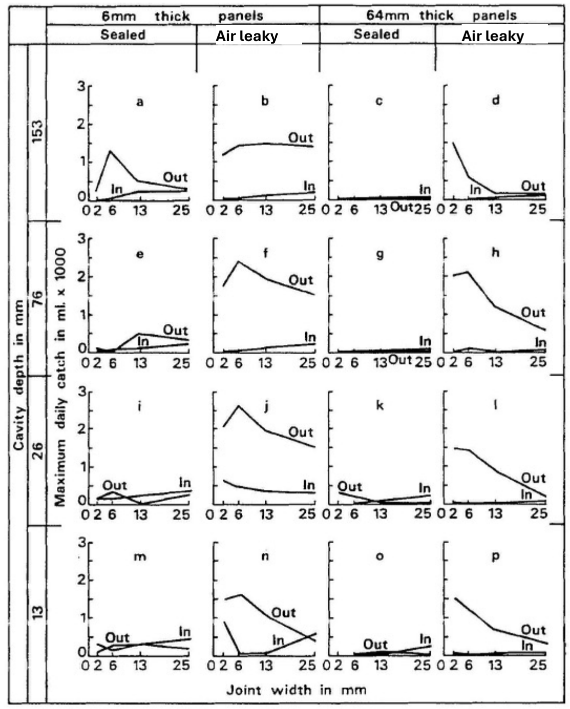
How much water crosses open joints?

- **BRE Field Study 1974**
- More water crosses cavity with thin panels, air leaky wall, thin cavity
- Eg Air leaky 1” cavity up to 65 oz/day w/ ½” wide joint





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Practical Implications for Design

- Small gaps drain .. but a gap of more than about 1/8” is needed to stop bridging
- Note: Larger gaps are important to provide
  - Ventilation air flow
  - Dimensional Tolerances
- We don’t have good information for *how often* to install flashing
  - Practical issues (fire, movement) likely govern
  - Drainage over many floors is generally fine

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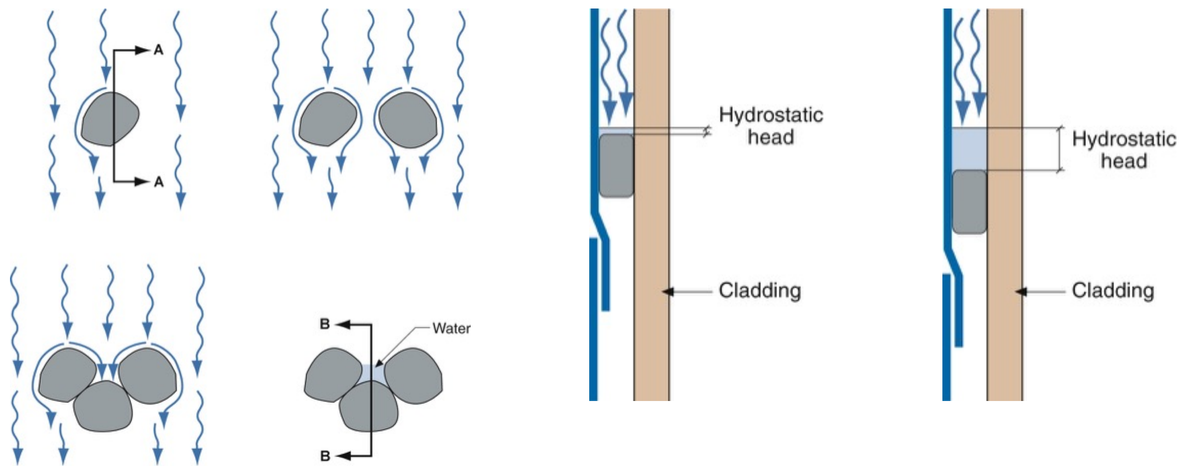
A critical 3D Drainage insight from Joe



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Internal Drainage Joints

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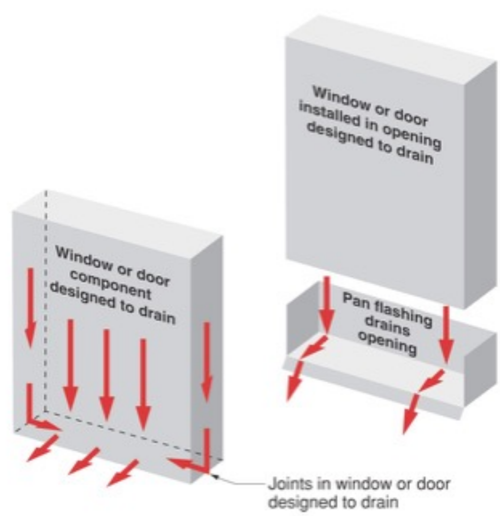
Components with Internal Drainage

- Windows, Curtainwalls, Doors
- Precast Panels
- Insulated metal panels



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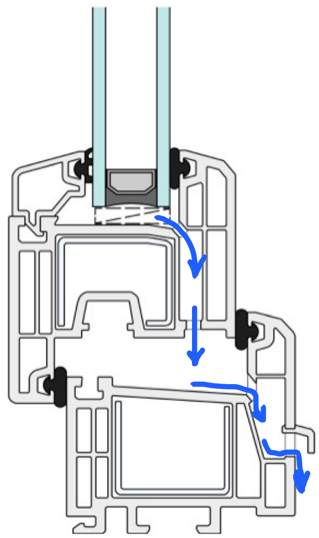
Window Frame Drainage



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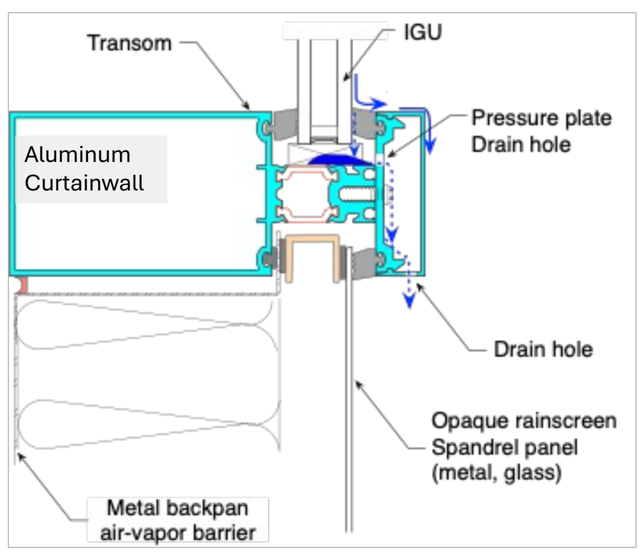
Curtainwalls, Patio door frame drainage



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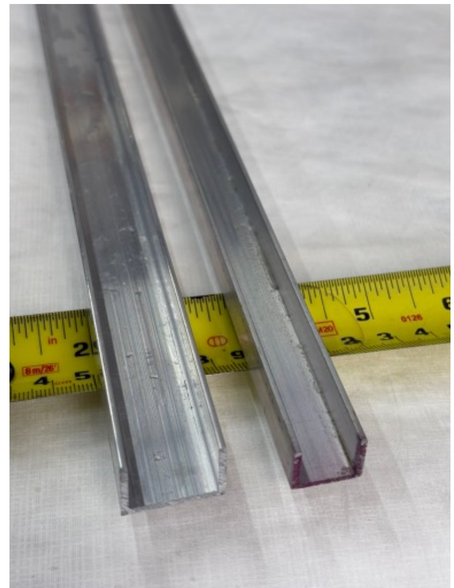
Aluminum Drainage Testing

- ½" and ¾" wide troughs
- Representative of many shapes in aluminum, PVC, and Fibreglass systems
  - Chose aluminum, but other materials may behave slightly differently



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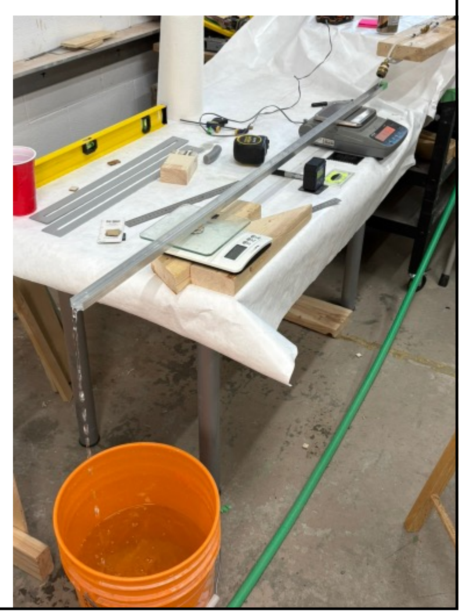
Lab Measured Curtainwall Drainage

- Aluminum troughs, ½" and ¾" wide x 4'
- Rate of water flow at zero slope
- Flow rate vs standing head of water
  - mL/min water vs mm of standing head
- Results:

1. high flow rates practical, i.e. 500 ml/min
2. Initial water stored before drainage
   - About 4.2-4.4 mm if still water
3. Not all water will drain
   - Usually drains to 2.8 – 3.0 mm



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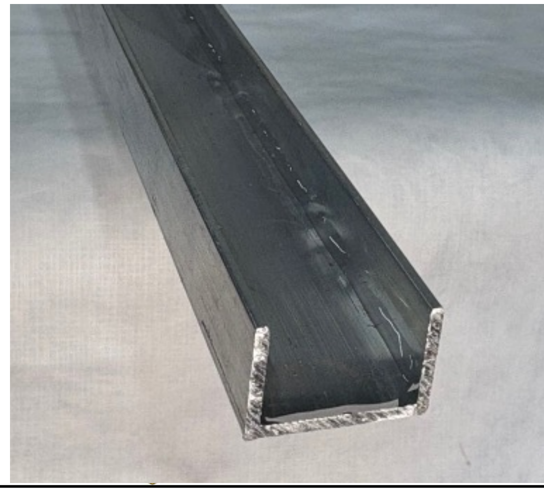
Internal Drainage troughs

- ½” stores 54 ml/meter (3/4 oz/foot) before drainage
- ¾” stored 84 ml/meter (1 oz/foot)



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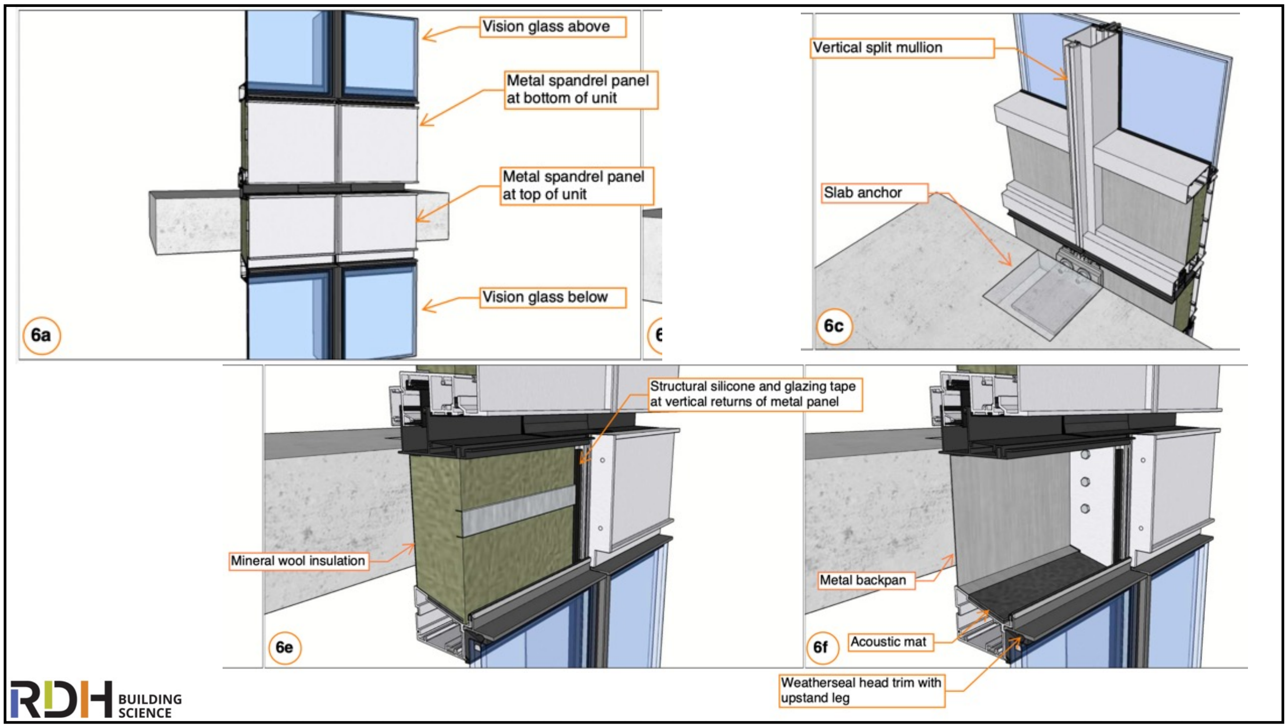
Vision glass above
Metal spandrel panel at bottom of unit
Metal spandrel panel at top of unit
Vision glass below
6a
Vertical split mullion
Slab anchor
6c
Structural silicone and glazing tape at vertical returns of metal panel
Mineral wool insulation
6e
Metal backpan
Acoustic mat
6f
Weatherseal head trim with upstand leg
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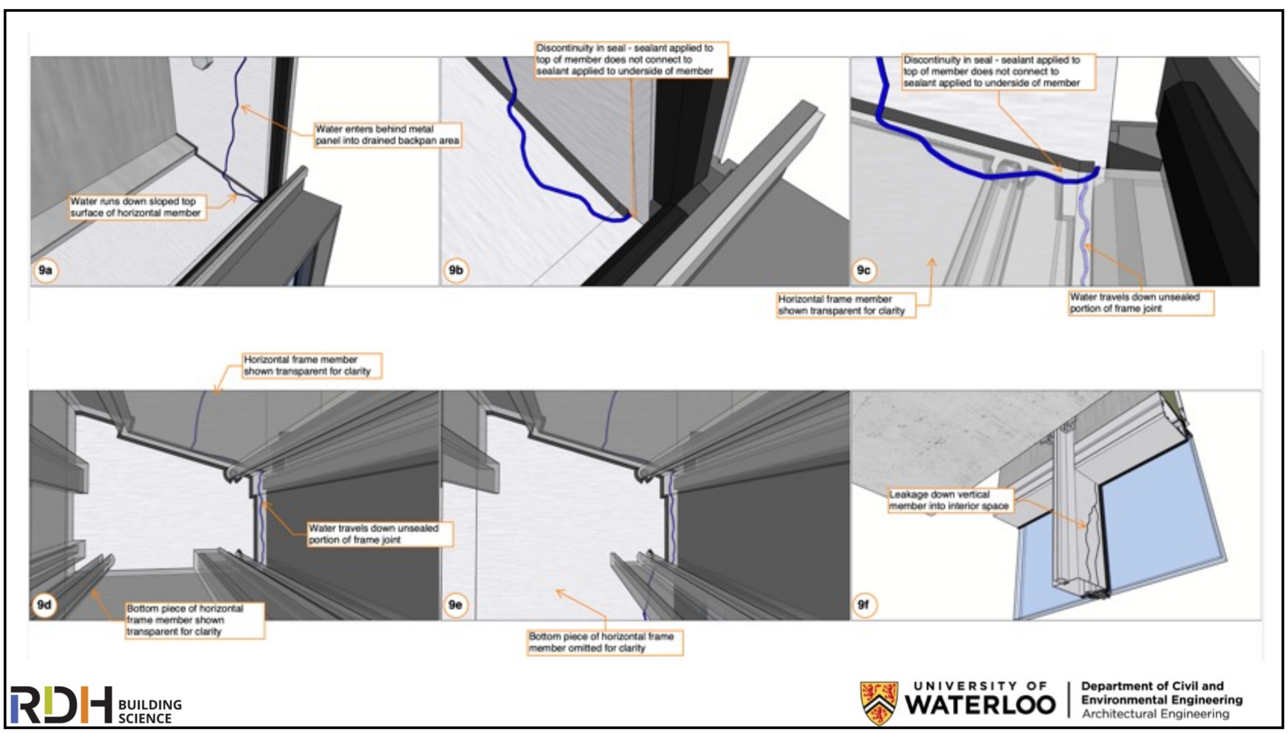
Water enters behind metal panel into drained backpan area
Water runs down sloped top surface of horizontal member
9a
Discontinuity in seal - sealant applied to top of member does not connect to sealant applied to underside of member
9b
Discontinuity in seal - sealant applied to top of member does not connect to sealant applied to underside of member
9c
Horizontal frame member shown transparent for clarity
Water travels down unsealed portion of frame joint
Horizontal frame member shown transparent for clarity
Water travels down unsealed portion of frame joint
9d
Bottom piece of horizontal frame member shown transparent for clarity
9e
Bottom piece of horizontal frame member omitted for clarity
Leakage down vertical member into interior space
9f
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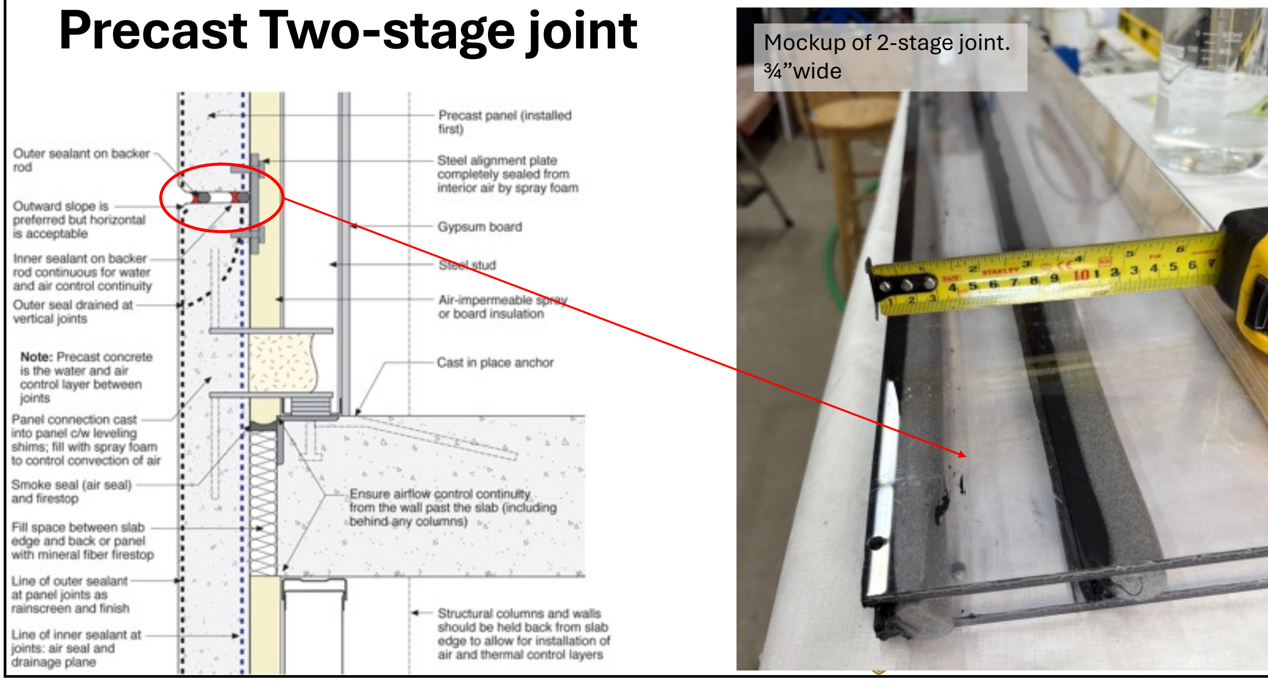
Precast Two-stage joint



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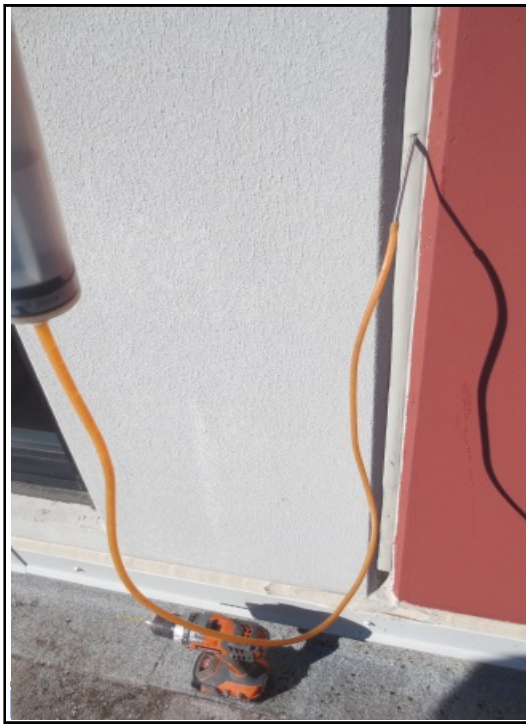

Non-standard Joint Drainage Test

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Does it drain? Test it?

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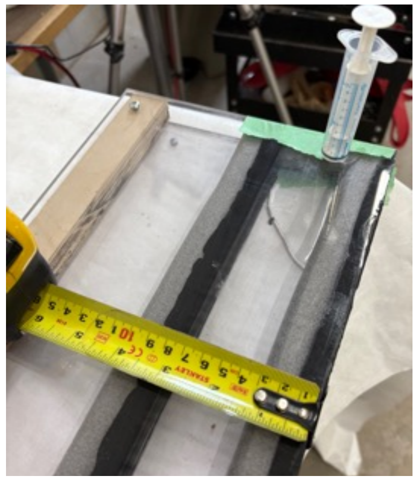
Lab Drainage

- Significant water storage before drainage
- In this case > 100 mL for 550 mm
- 4 oz/ 2ft



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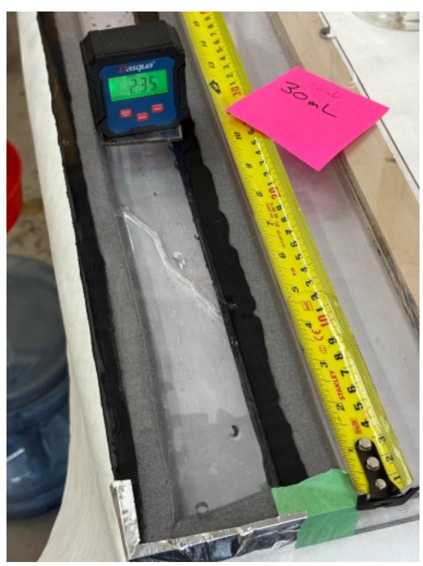
Drainage with outward slope



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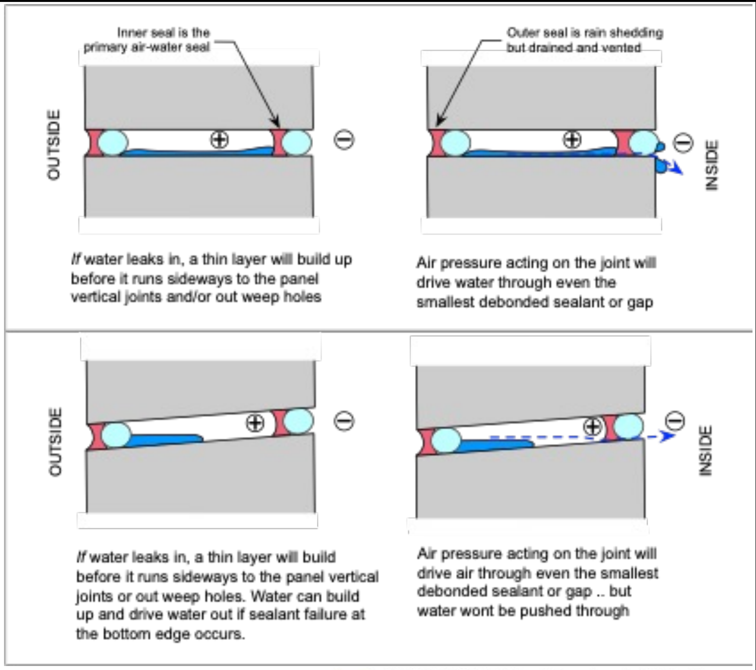
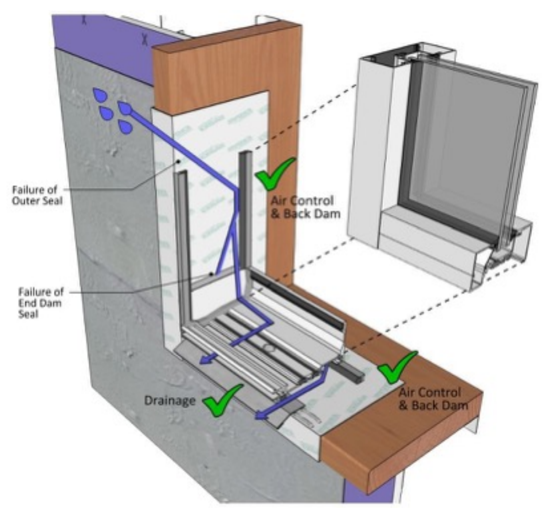
Precast

- Applies to most horizontal joints
- Slope needs to be enough to move water
- E.g. in these tests, more than about 5 degrees



Window Sill Rough-Opening Drainage

- A bit like a precast panel joint!
- Water will be stored then drain sideways to weep hole



Matthew Ayers, McCownGordon Construction

Conclusions

- Drainage matters!
- More to learn about details
- Focus on slope and continuity, not gap size

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