Introduction

- This session will look at applications for **wood** and **concrete structural** and **enclosure** systems, providing state-of-the-art expertise on choosing the right material for the project, and applying building science principles to construct resilient, durable, long-lasting, and healthy, energy-efficient buildings.
- UW- research on new wood systems
- RDH- assess options for clients @ early stage

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Material Selection Matters

Dr John Straube, P.Eng.
Principal, RDH Building Science
Professor, School of Architecture
University of Waterloo

Outline

- Materials
- Structural Systems
- Enclosures

- Concrete
- Steel
- Wood

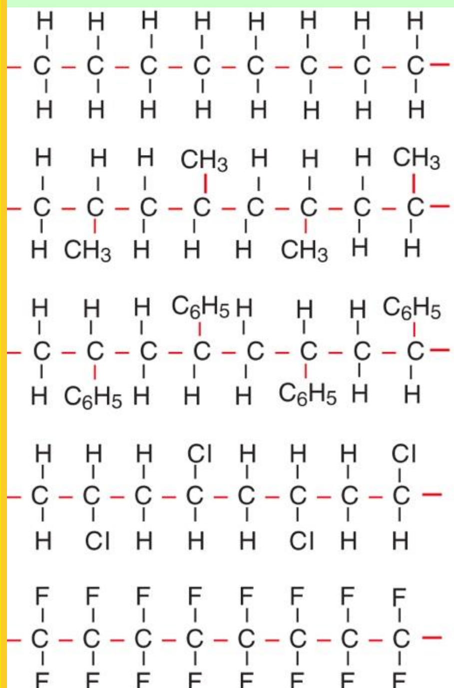
- Trends, Research and Field Experience

SOME MATERIAL SCIENCE

Materials – Basic Review

- **Agents of material deterioration**
  - Water
  - Oxygen
  - UV
  - High heat / very cold
  - Fire
- **Three primary material categories**
  - Metallic
    - Corrosion=oxidation
  - Polymer/organic
    - UV, oxidation, high heat, cold, moisture (natural polymers)
  - Mineral/Ceramic
    - Freeze-thaw, salt
  - Composite: made up of others

Polymers: Carbon bonds



Polyethylene, **PE**

Polypropylene, **PP**

Polystyrene, **PS**

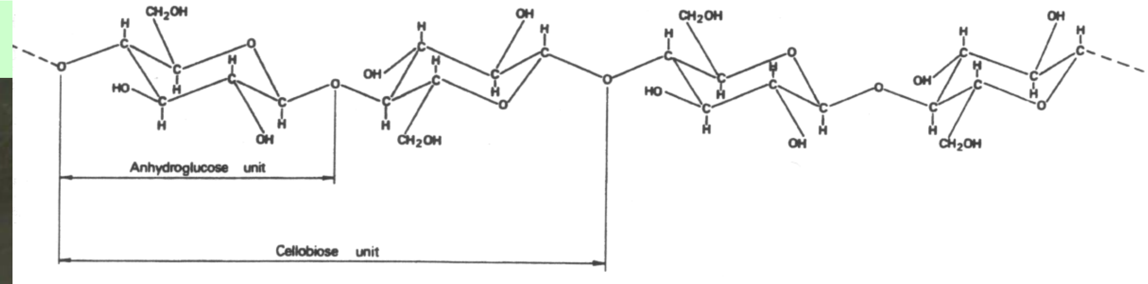
Polyvinyl chloride, **PVC**

Polytetrafluoroethylene, **PTFE**

Asphalt– a modified natural polymer

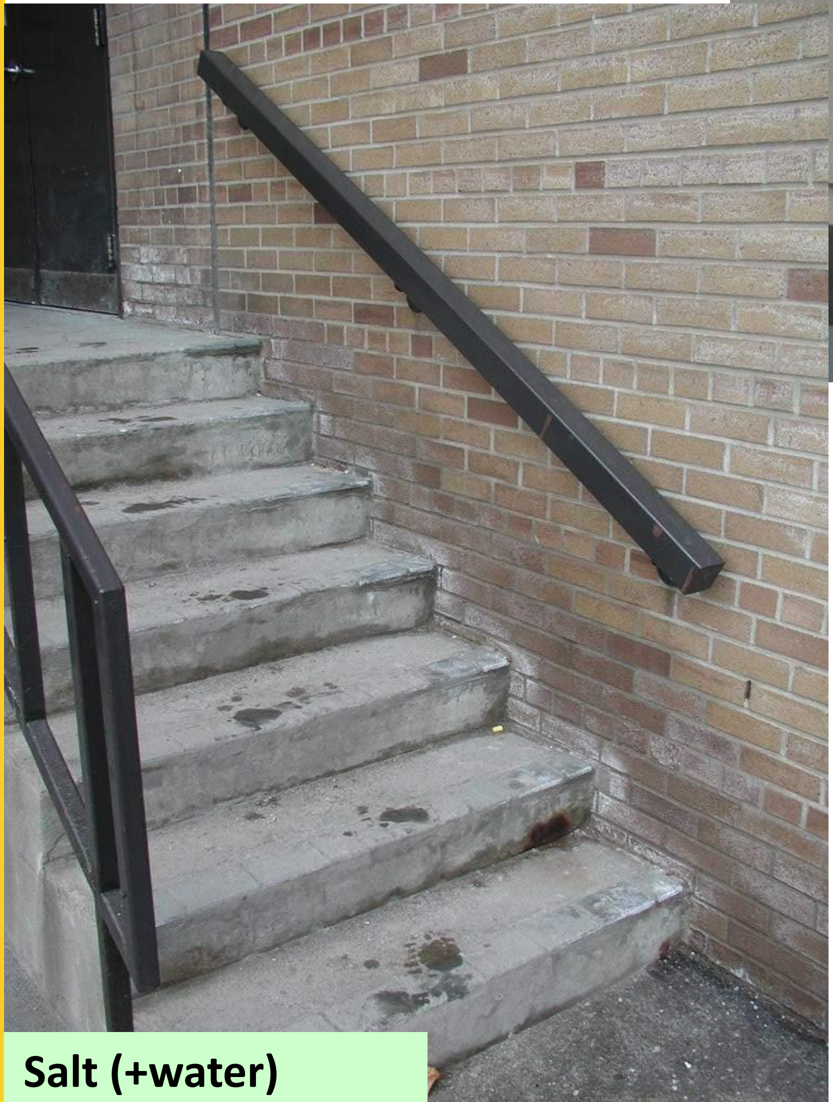
e.g. Minerals used to protect polymer from UV

Wood: a natural polymer



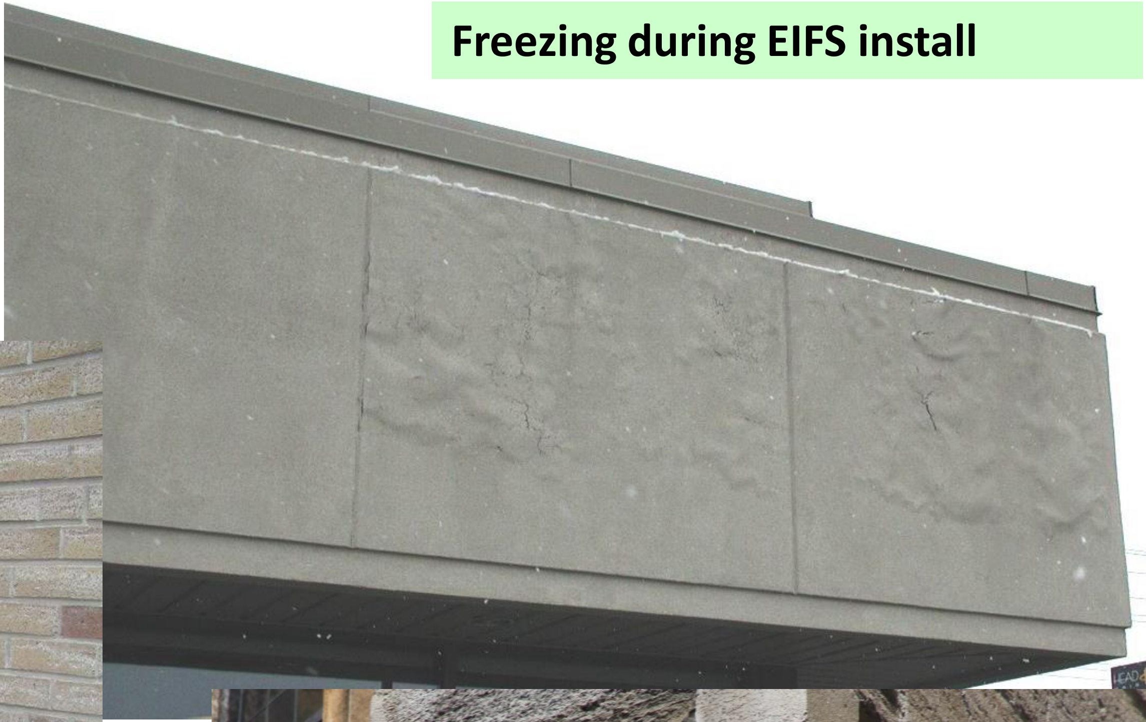
Clay Brick: a time-tested mineral-based product

Many other mechanisms of specialist interest



Salt (+water)

Freezing during EIFS install



Stone: being dissolved slowly

THE CHANGING WORLD

New Challenges / Trends

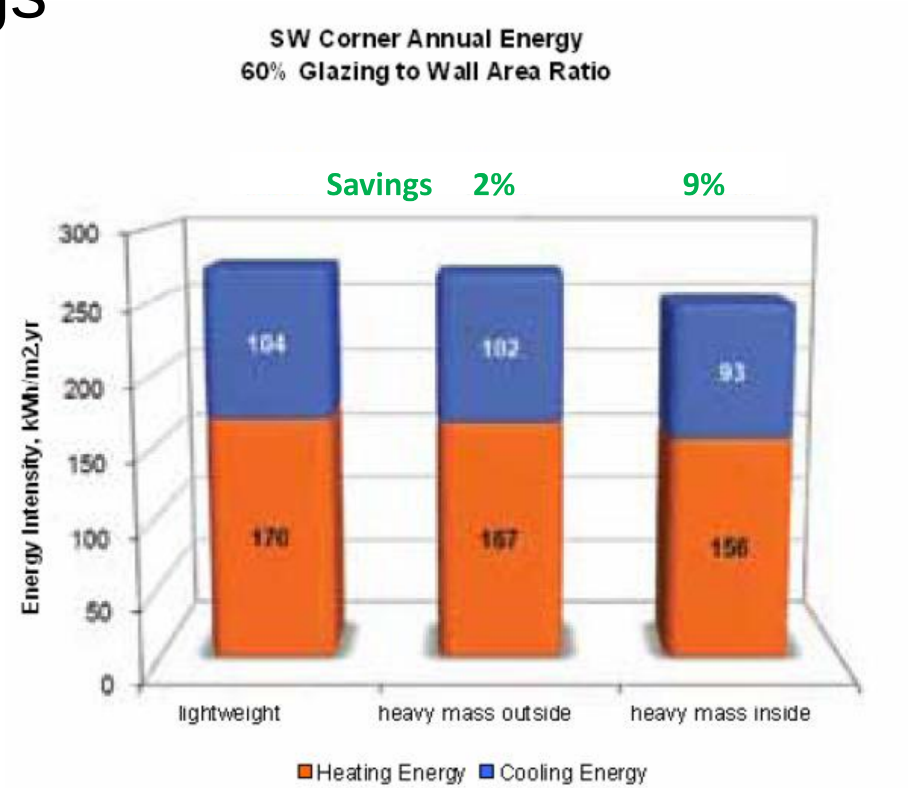
- Faster construction & design cycles
  - All weather construction
- Congested sites
  - i.e., urban & additions
- More High-rise & multi-use
- Better Energy performance
  - More on this later…
- Climate Change & Resiliency
- Design for Maintenance & Renewal

Building Energy Use

- Growing demand from codes and some customers for lower energy use
- Actual measured performance beginning to play a role- game changer
  - Models vs reality
  - Code compliance vs performance
- Energy use is a SYSTEM and DESIGN issue not a material issue
  - Continuous insulation, air barrier are critical!

Aside: Thermal mass & Energy

- Thermal mass can improve comfort, resiliency, and save energy
- Mass in exposed ceilings is most valuable
- Exterior walls also helpful- but keep it inside

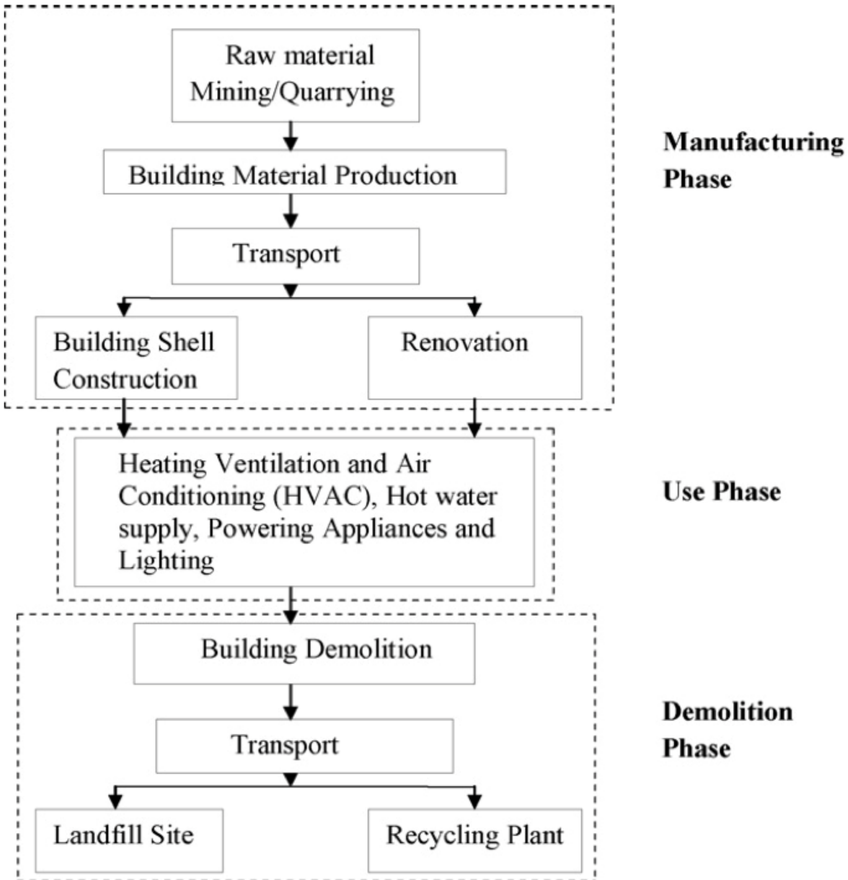


RDH Study of Vancouver MURB

MATERIALS AND STRUCTURAL SYSTEMS

Aside: Embodied Energy

- Operation / use comprises 80-90% of life-cycle energy of common buildings
- Material choice is a small overall factor
- Energy-efficiency & design-efficiency are 90-95%
- Durable buildings are lower GHG



Different Occupancies / Different Needs

- Residential
  - Compartments: fire, sound, odour
  - Many good internal partitions
    - Concrete / CMU vs framed hollow
- Office
  - Wide open flexible spaces, lots of services
  - Concrete or steel with concrete topping
- Retail
  - Very few partitions

Past: the last 50+ yrs

- Wood
  - Low-rise, single-family
  - Some three+ storey multi’s
- Masonry
  - Low- & mid-rise institutional/commercial
- Concrete Frame
  - Mid- & high-rise institutional/commercial/resid.
- Steel Frame
  - Low- to high-rise commercial (some instit.)

Why?

- Why were those choice made?
- Usually because the different choices were deemed best for different needs
- High-rise is more expensive than low-rise
  - Higher loads, higher fire resistance, more durability expectations
- None of the material properties has changed
  - Why are choices changing?
  - Labour, energy, performance expectations

Future material selection

- Building designers need to change to meet
  - More labor efficient (price)
    - prefab
  - Higher density means
    - Taller buildings, people next to each other
    - Fire and sound more important!
  - More energy efficient
    - More insulation, more airtightness, less thermal bridges
  - Building in any weather, fast
    - Prefabrication, less moisture sensitive

In the old days …

Labour & time expensive

Wood single-family housing

- Low-cost
- Easy to escape in fire
- Sufficient load capacity (if connected)
- Separation for fire/noise by air gap or CMU

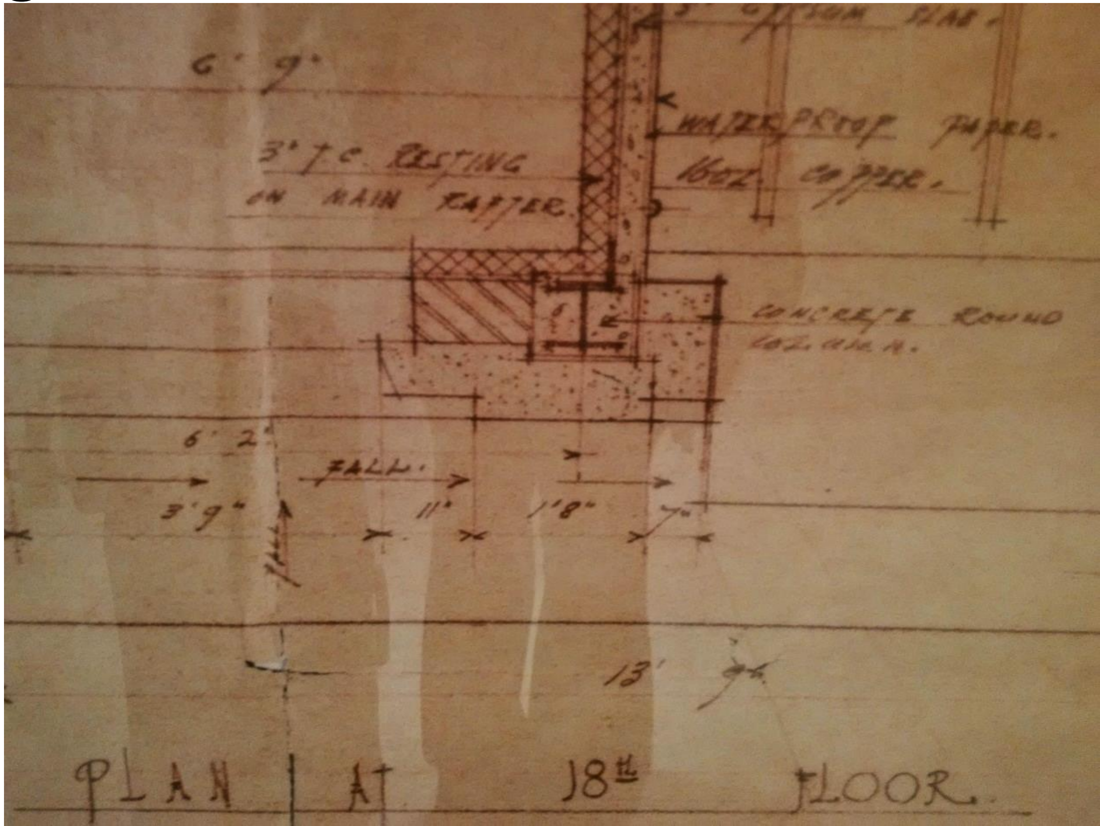
Hot-rolled Steel Frame

- Low weather sensitivity
- Fast erection
- Requires significant additional fire protection esp. for taller buildings
- Requires enclosure system (like all frames)
- Requires partition system (like all frames)

Low-rise spec. office building
Additional finish, fire protection
and sound isolation needed

Site-cast Concrete Frame

- Integral Fire-proofing
- Shear walls / floor can be excellent fire/sound separating partitions
- Cold-weather sensitive
- Need repetition in formwork to be economical



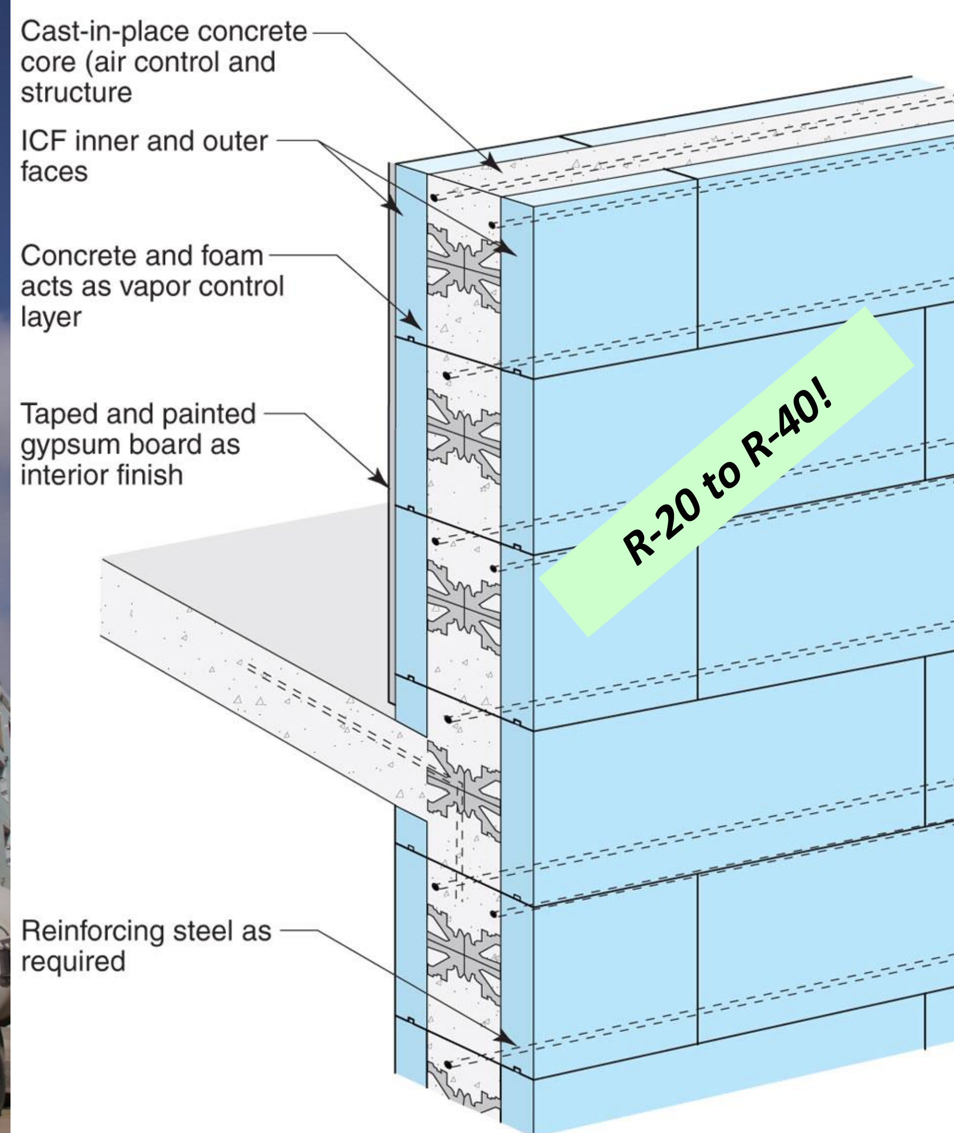
Institutional building
Strong, durable, fire/sound resistant
Flexible floor plan
Cold weather heating…

Concrete Masonry Mid-rise

Investor-owned building
Strong, durable, fire/sound resistant
Fixed compartments
Masonry= labour expensive, weather

Insulated Concrete Forms

Emerging technology
Includes enclosure thermal/air
Less weather/formwork sensitive
Foam needs fire protection/finish



ICF

- High rise practical – manage window widths

Total Precast (MURB)

Investor Owned
Fast erection, excellent fire sound separation
Little weather sensitivity

Waterloo, ABA Architects

Sandwich panel

R-20 or so

Fast erection, excellent fire sound separation
Little weather sensitivity
Pefab w/windows in factory

Tall Wood Buildings

- Much closer Framing
  - Not practical much beyond 6 stories
- Cross-Laminated Timber
  - Can be used for tall building
- Post-and-Beam
  - Can easily be 10 storeys with big enough wood
- Wood-frame infill
  - Any height structurally…

Four+

Six-storey Mid-Rise Wood Buildings (framed)

6 storeys is very different . . .

- Price rockets as the amount of wood doubles
- Connections!

CLT- new kind on the block

- New: Solid wood strips, cross laminated
- Much stronger, heavier, more fire resistant
- Much more costly

Solid wood:CLT

Contents lists available at ScienceDirect

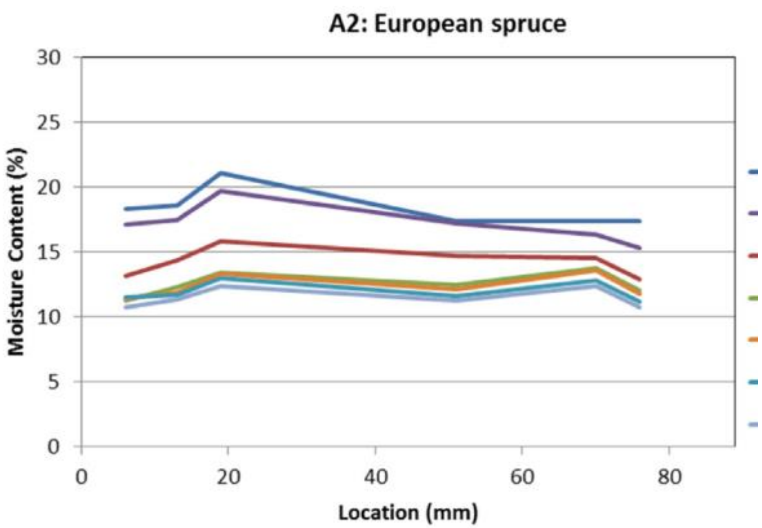
Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

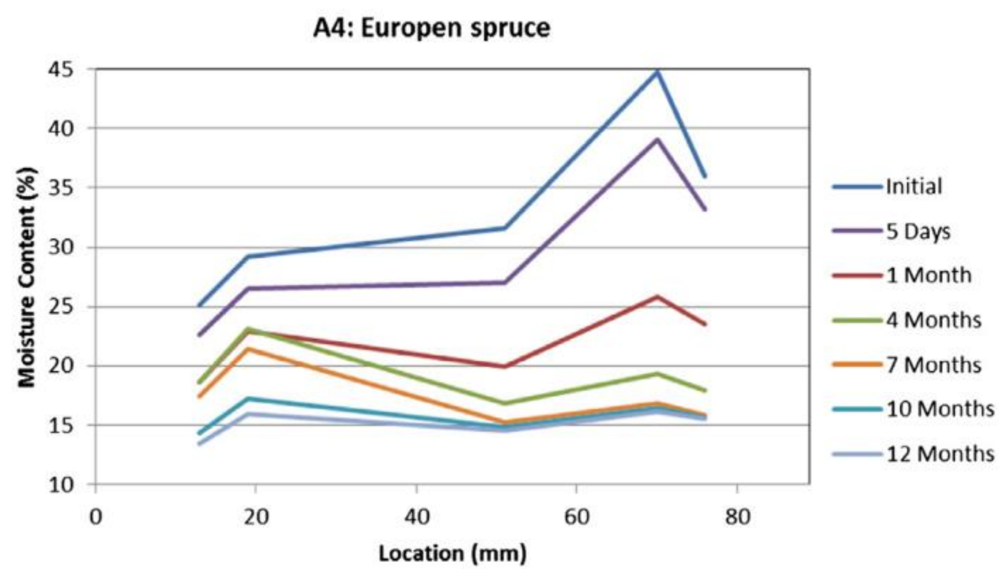
Hygrothermal performance of cross-laminated timber wall assemblies with built-in moisture: field measurements and simulations

Ruth McClung [a], Hua Ge [b,*], John Straube [c], Jieying Wang [d]

[a] Morrison Hershfield, Vancouver, Canada
[b] Concordia University, 1455 de Maisonneuve, Montreal H3G 1M8, Canada
[c] University of Waterloo, 200 University Avenue West, Waterloo N2L 3G1, Canada
[d] FPInnovations, 2665 East Mall, Vancouver V6T 1Z4, Canada



High permeance interior and exterior



Low permeance interior & medium exterior

High-rise Around the World

•

7 storeys - e3, Germany, Kaden & Klingbeil Architects

8 storeys – LCT One, Austria, Hermann Kaufmann

8 storeys – Finland, OOPEAA

9 storeys – Melbourne Australia, Land Lease

9 storeys – Murray Grove, UK, Waugh Thistleton Architects

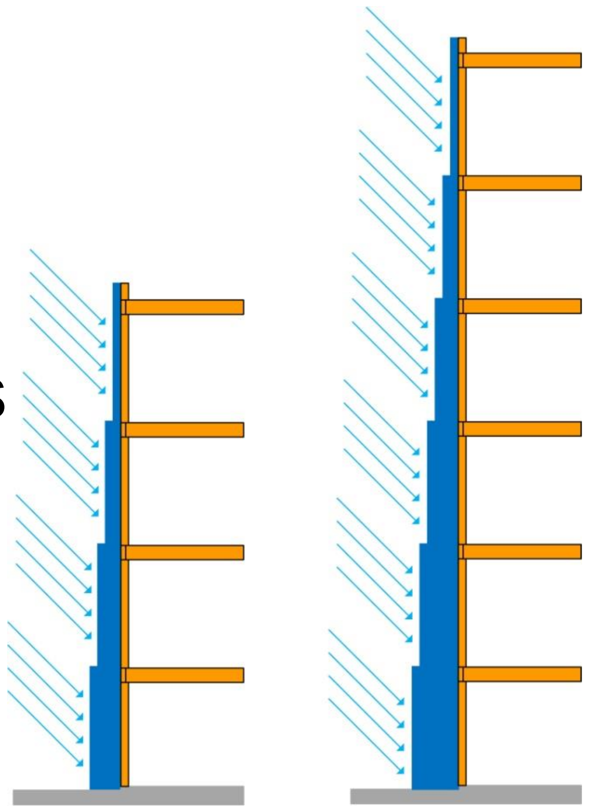
Michael Green Architecture (MGA) – Contractor: PCL Construction

We can …

- … but should we?
- Significant complexity to manage
  - Many layers, trades, details
- New challenges to overcome
  - Construction moisture
  - Shrinkage/movement
  - Fire

Increase in Wind and Rain Loads

- Specified structural and water penetration performance criteria for windows
  - Some low-rise windows may not work as well in mid-rise buildings
- Cumulative runoff
  - Water shedding features become more important
    - continuity, drip edges
  - Water penetration control strategy



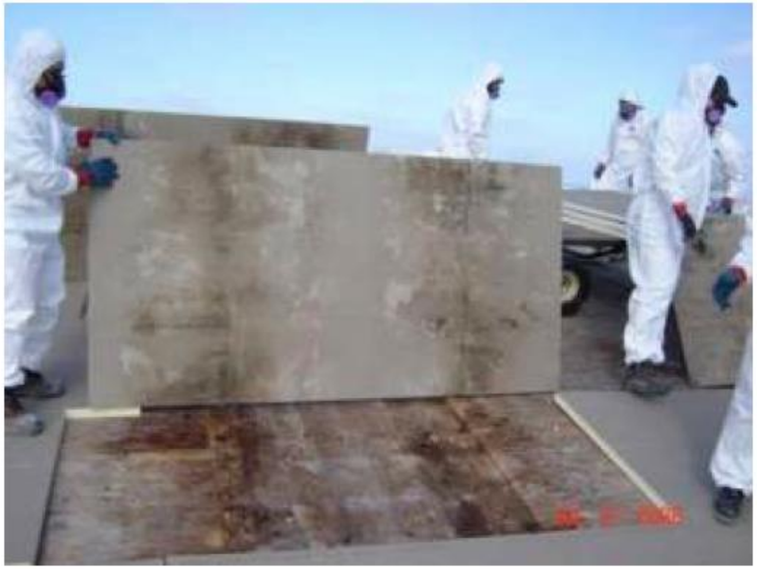
Challenges with Mechanically Attached Air-Water Barriers & Wind During Construction

Construction Moisture

- taller buildings exposed to more rain and snow
- More concerns re water storage/damage

Moisture Trapped in wood

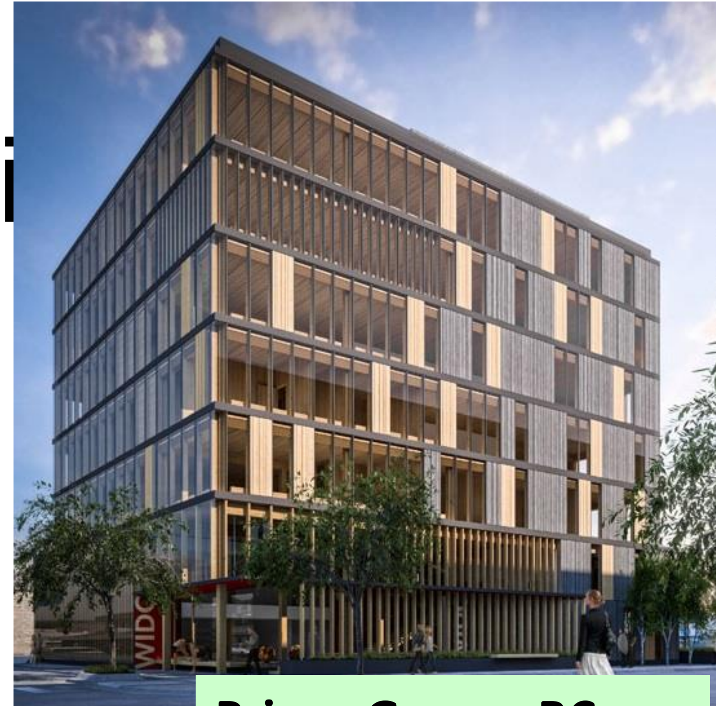
- Don't use organic (paper) faced insulation in contact with damp wood



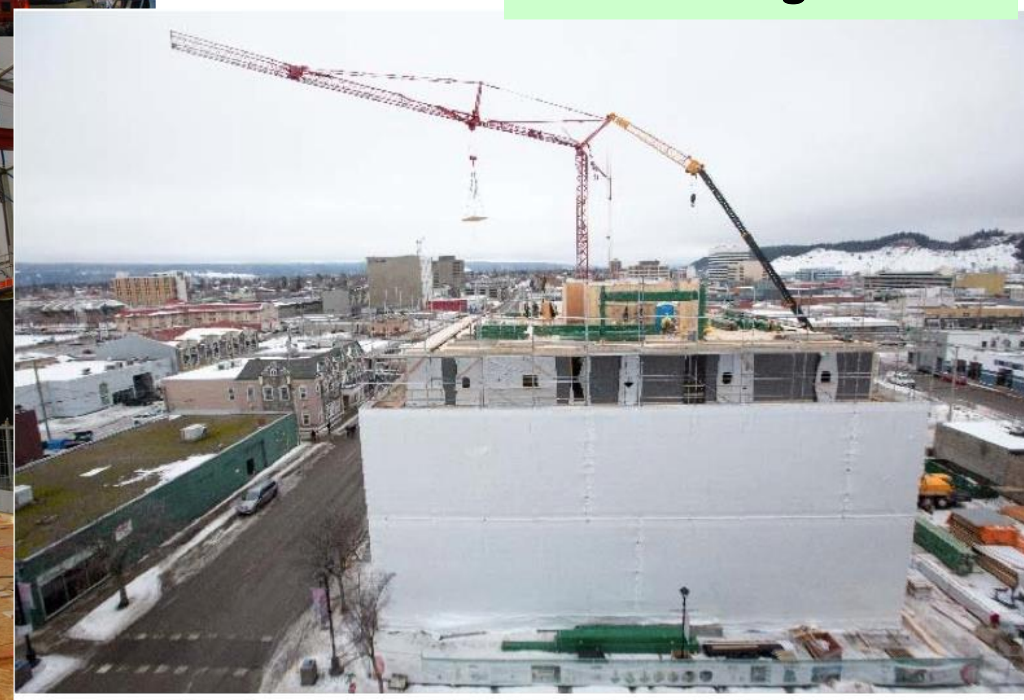
Drying of a wetted roof by natural means through **more than one layer of plywood** can be very slow

Finland

ecti

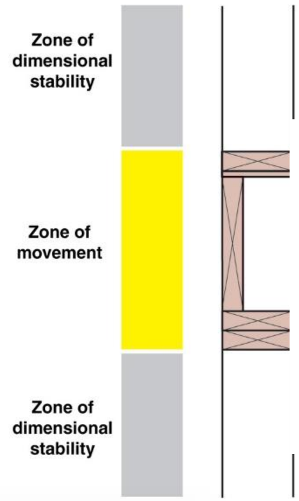


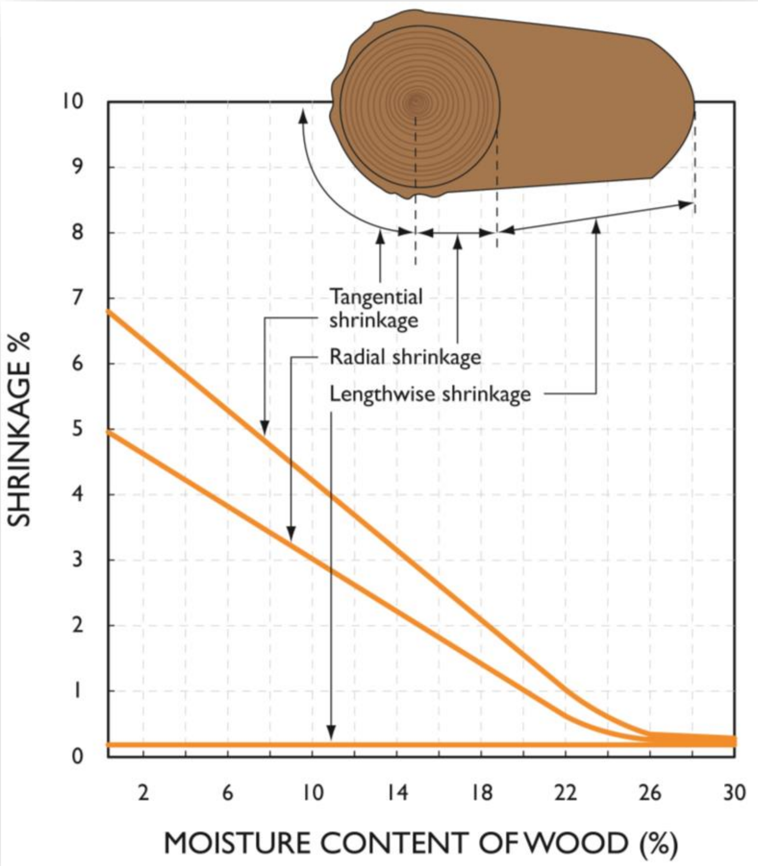
Prince George BC

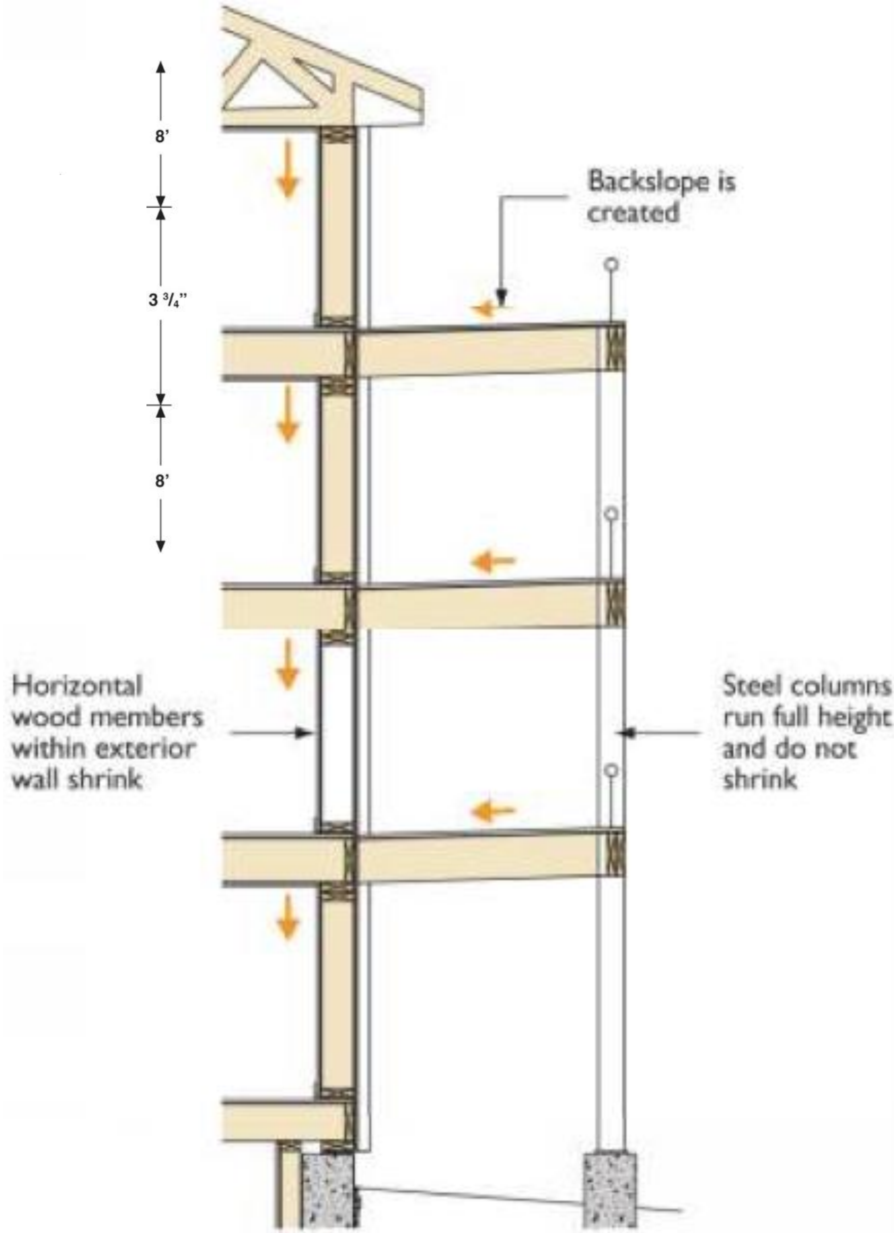


Shrinkage

- Cross-grain wood shrinks



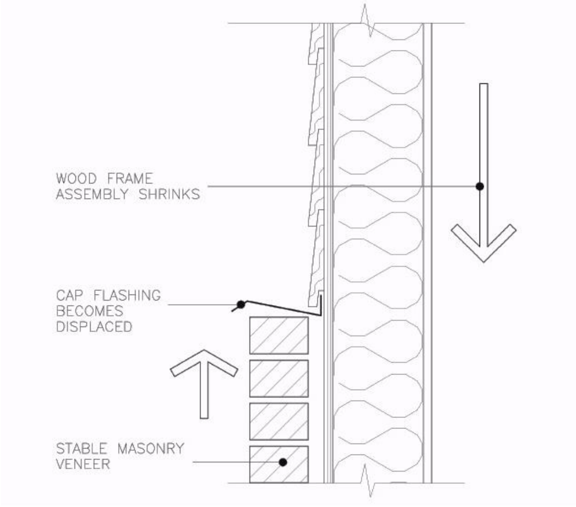


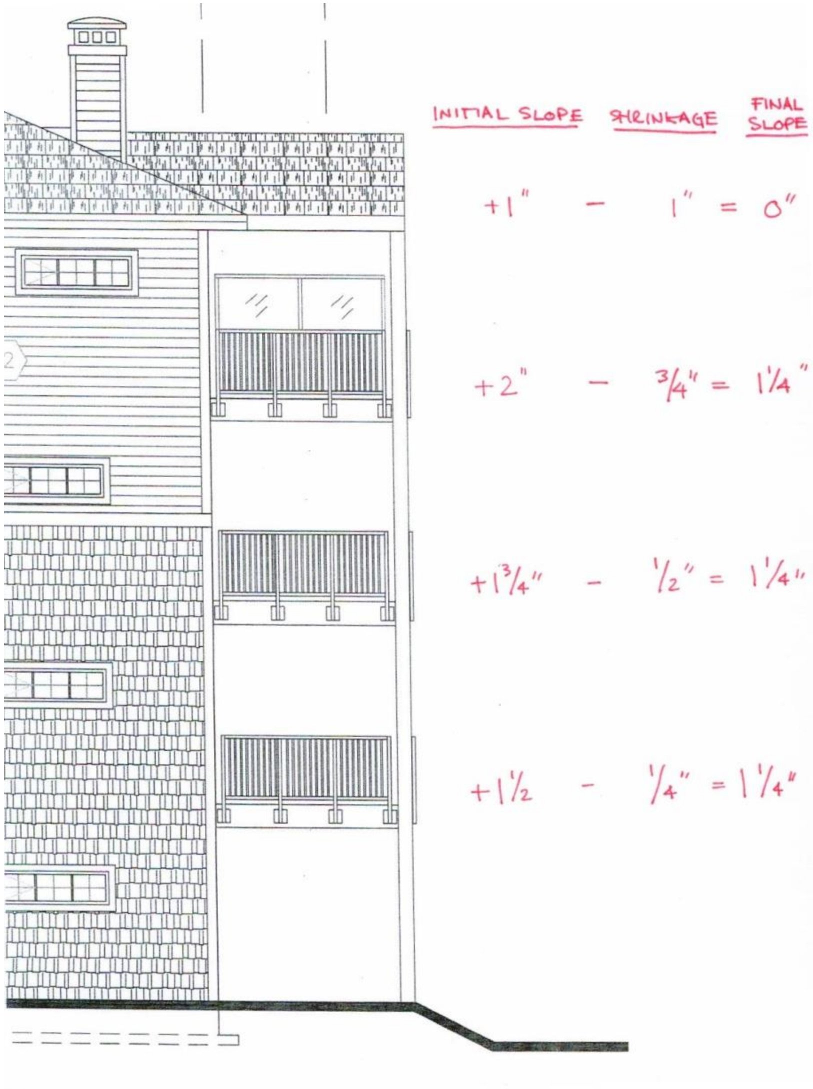


Differential Shrinkage

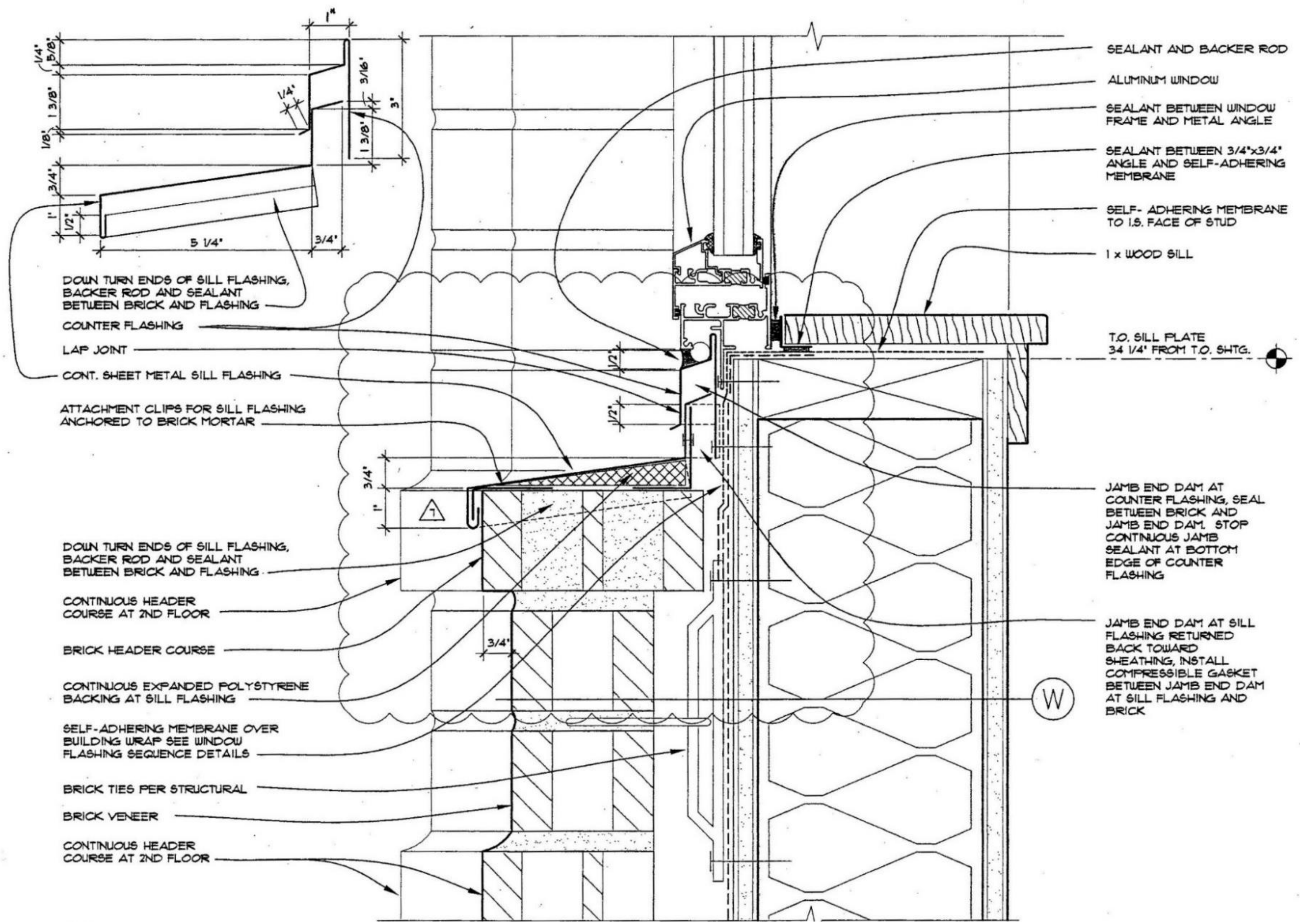
Out of the Comfort Zone

- Wood frame and masonry or concrete walls (fire walls, stairwells, elevator core)
- Masonry cladding
- Floor and roof penetrations (plumbing, sprinkler pipes, tops of masonry walls)
- Different support structure (balconies with exterior columns)





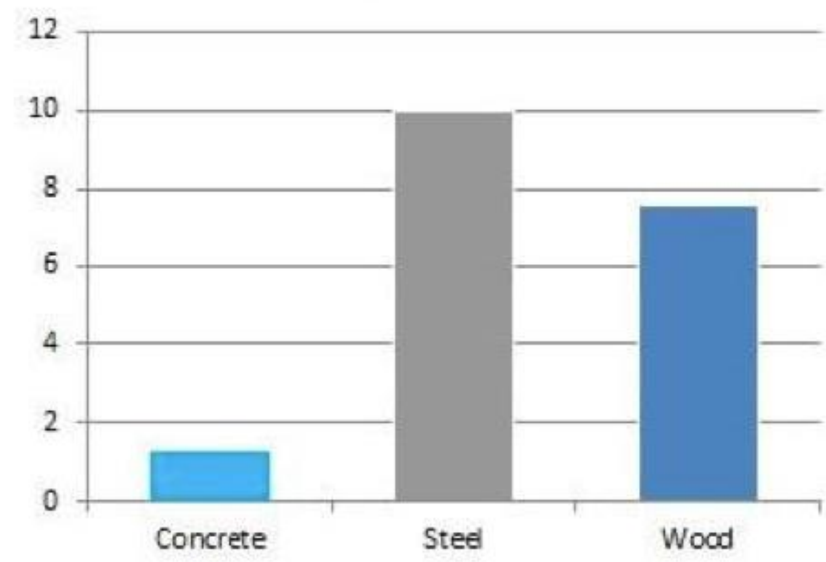
Windowsill sliding flashing to accommodate shrinkage



Fire during construction

- Can you get insurance?

Figure 12: Percent of Each Building Type Demolished Because of Fire Damage



Source: O'Connor and Dangerfield (2004)

SOME ENCLOSURE ASPECTS

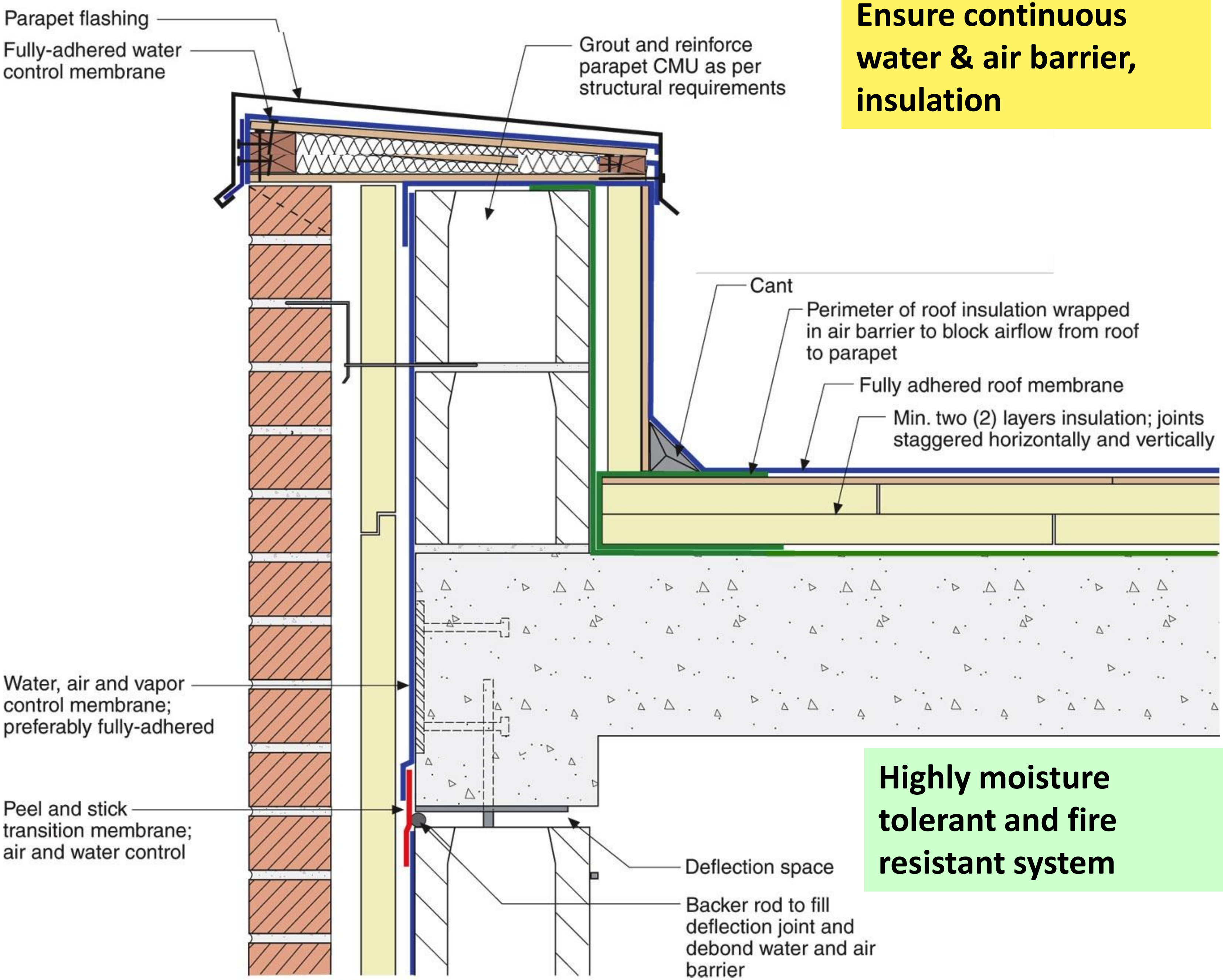
Many ways to enclose …

Building Elements - Envelope

Contractors perspective– PCL Constructors

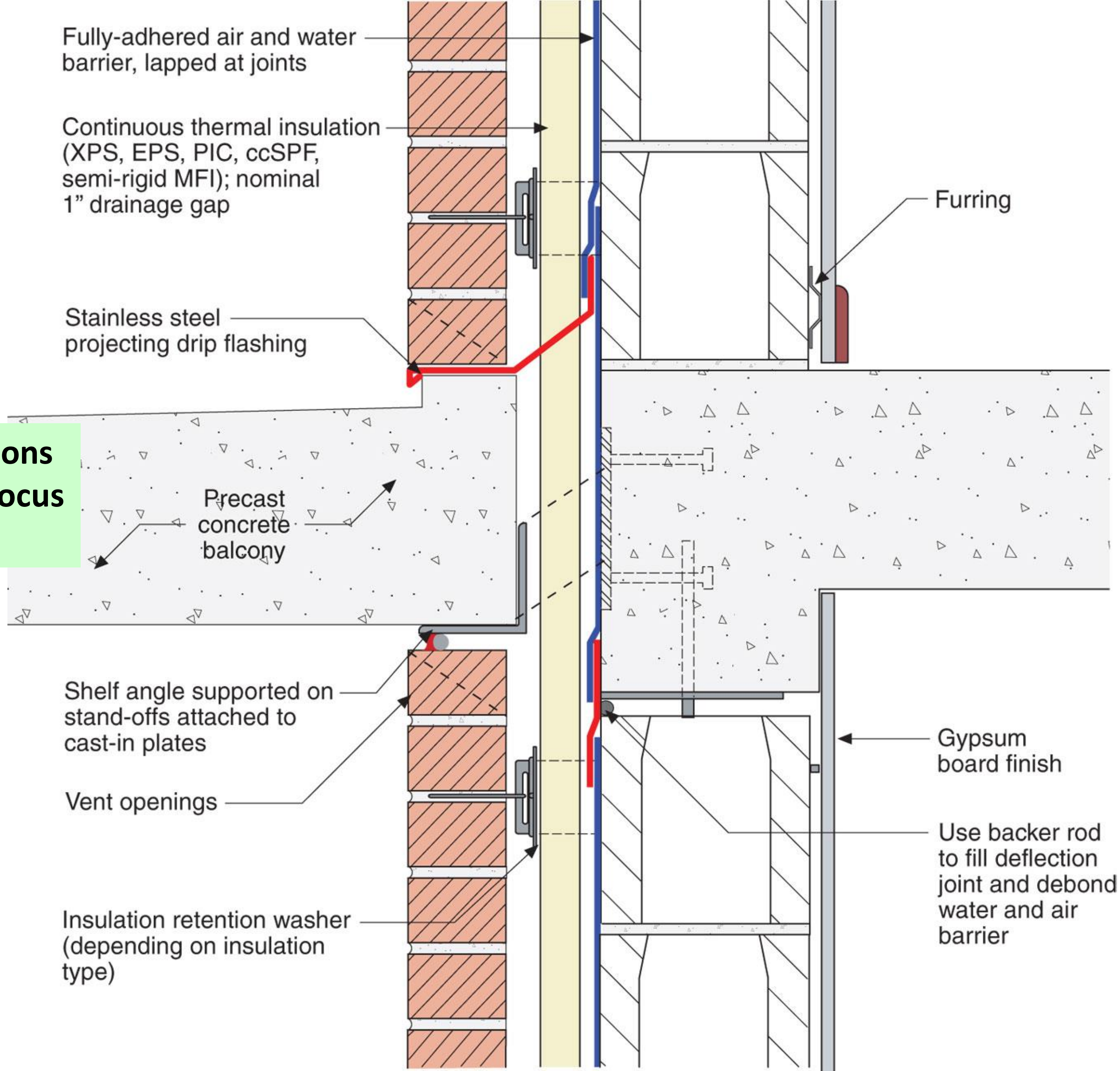
PCL

Ensure continuous water & air barrier, insulation



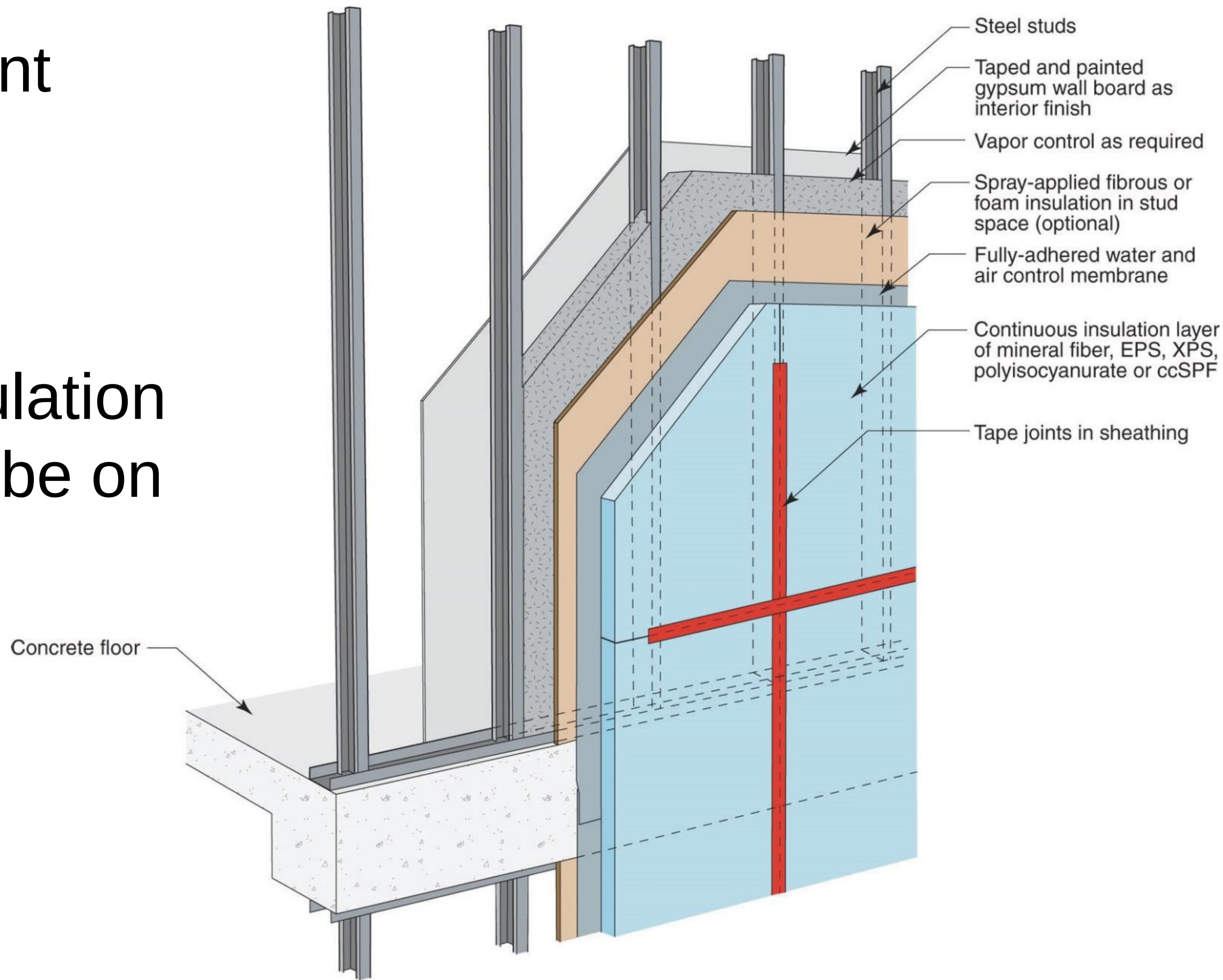
Highly moisture tolerant and fire resistant system

Detailing penetrations continues to be a focus
Forgiving system



Steel stud infill

- Significant on-site & on-wall work
- Most insulation needs to be on exterior



Curtainwall

Prefabricated/Unitized but, modern curtainwalls, window walls are around R-3 to R-4 including spandrels and have lots of hidden sealant

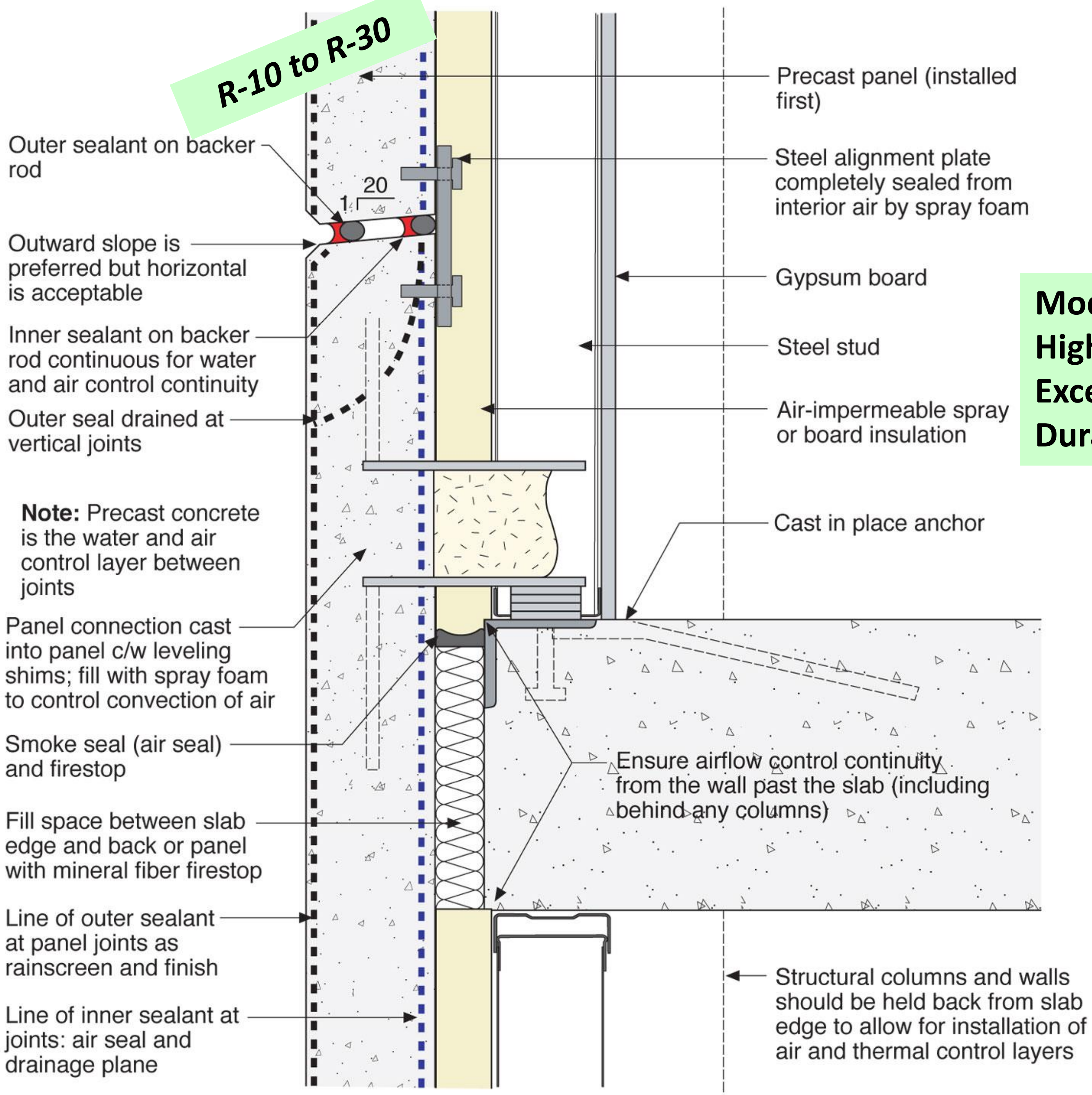
Architectural Precast

Federal Reserve
Minneapolis MN
HOK Architects

Commercial/Retail
Calgary, AB

FBI HQ
Buffalo, NY

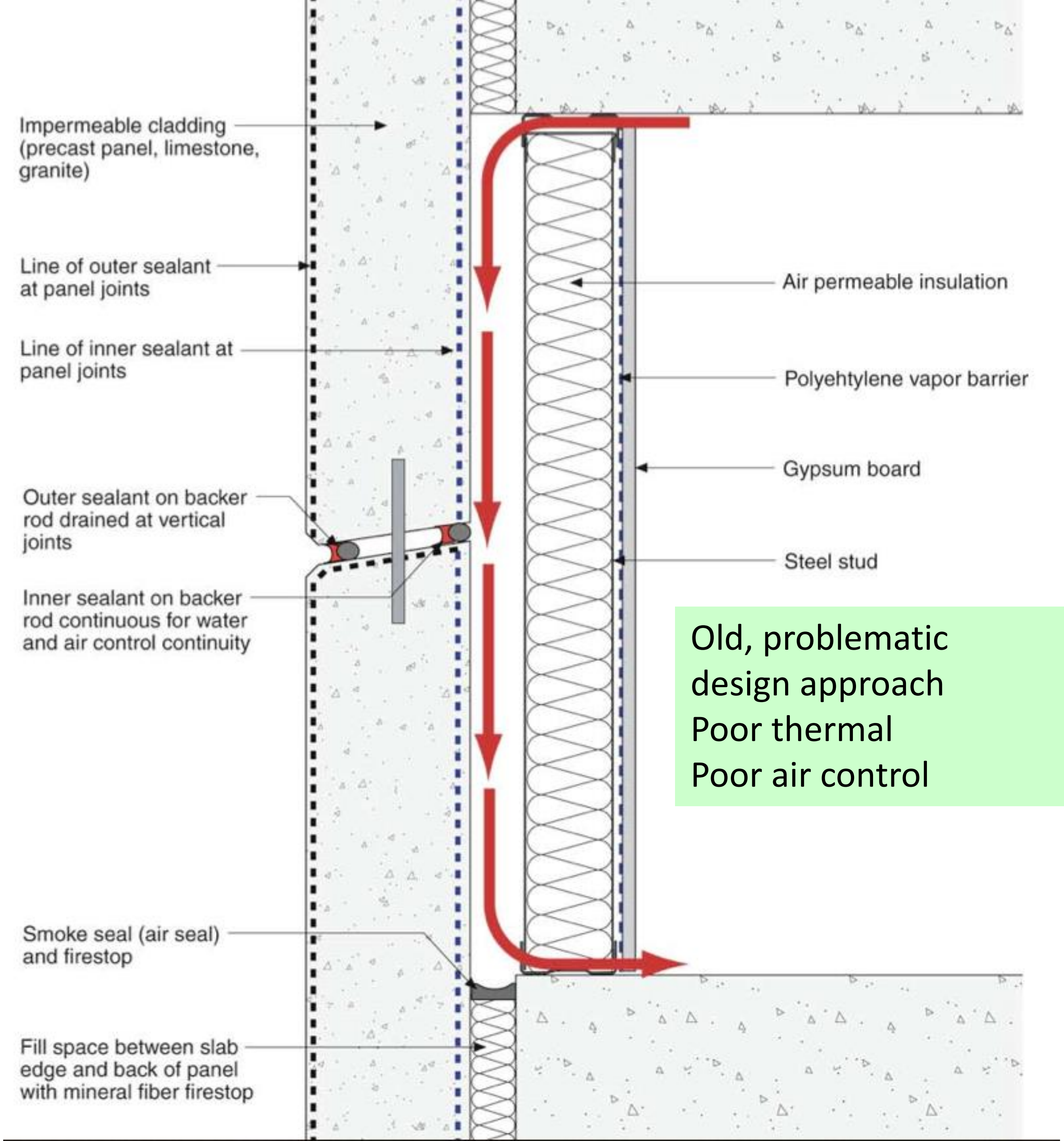
John Straube



Modern Approach
High thermal
Excellent air / water
Durable

Don't do this!

Avoid Air Gap!!
Provide continuous "convection" barrier inside (e.g., sealed gypsum, taped board foam, taped foil-face



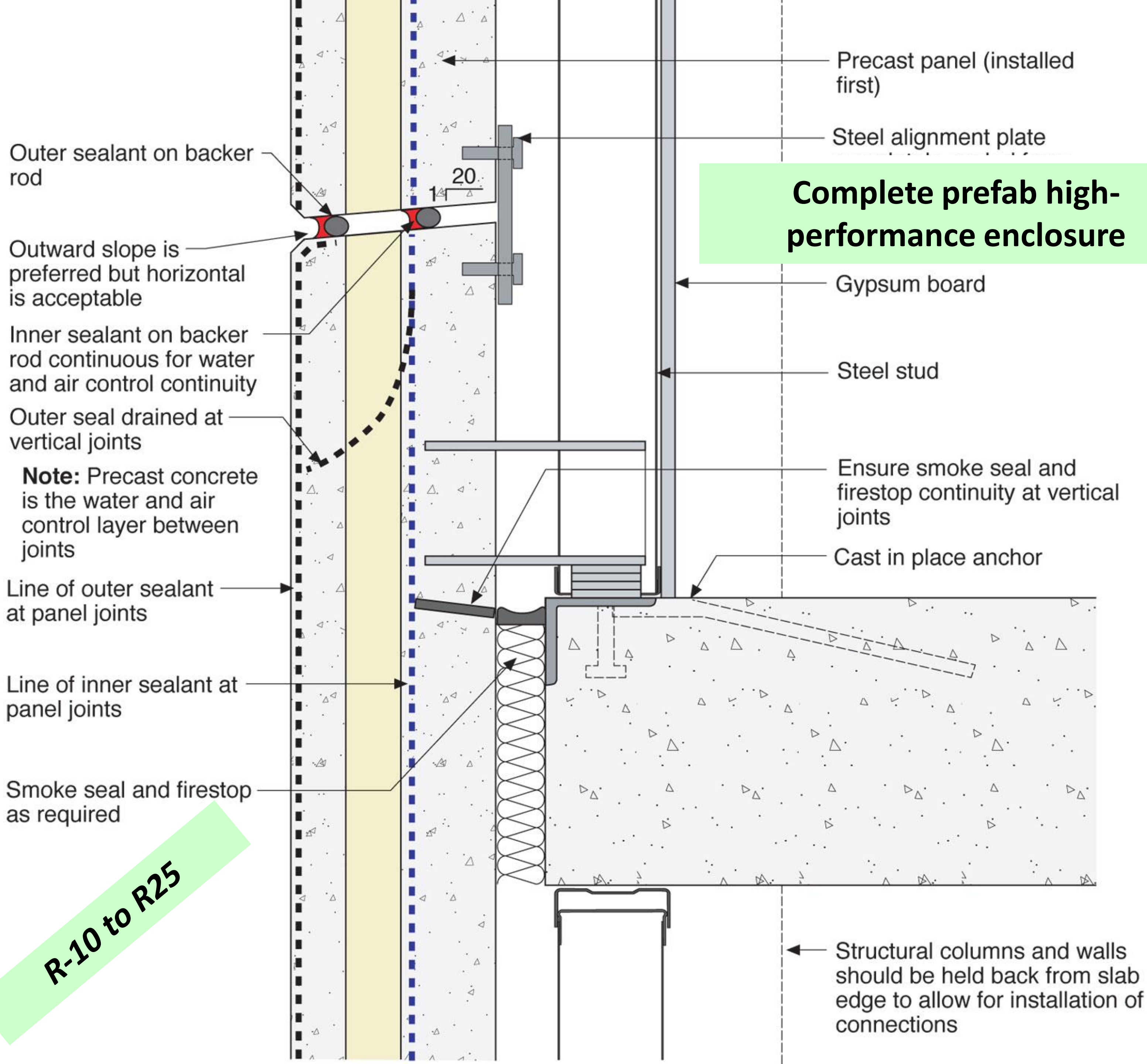
Old, problematic design approach
Poor thermal
Poor air control

Wide range of aesthetics

Waterloo Region Courthouse

NORR Architects

Complete prefab high-performance enclosure

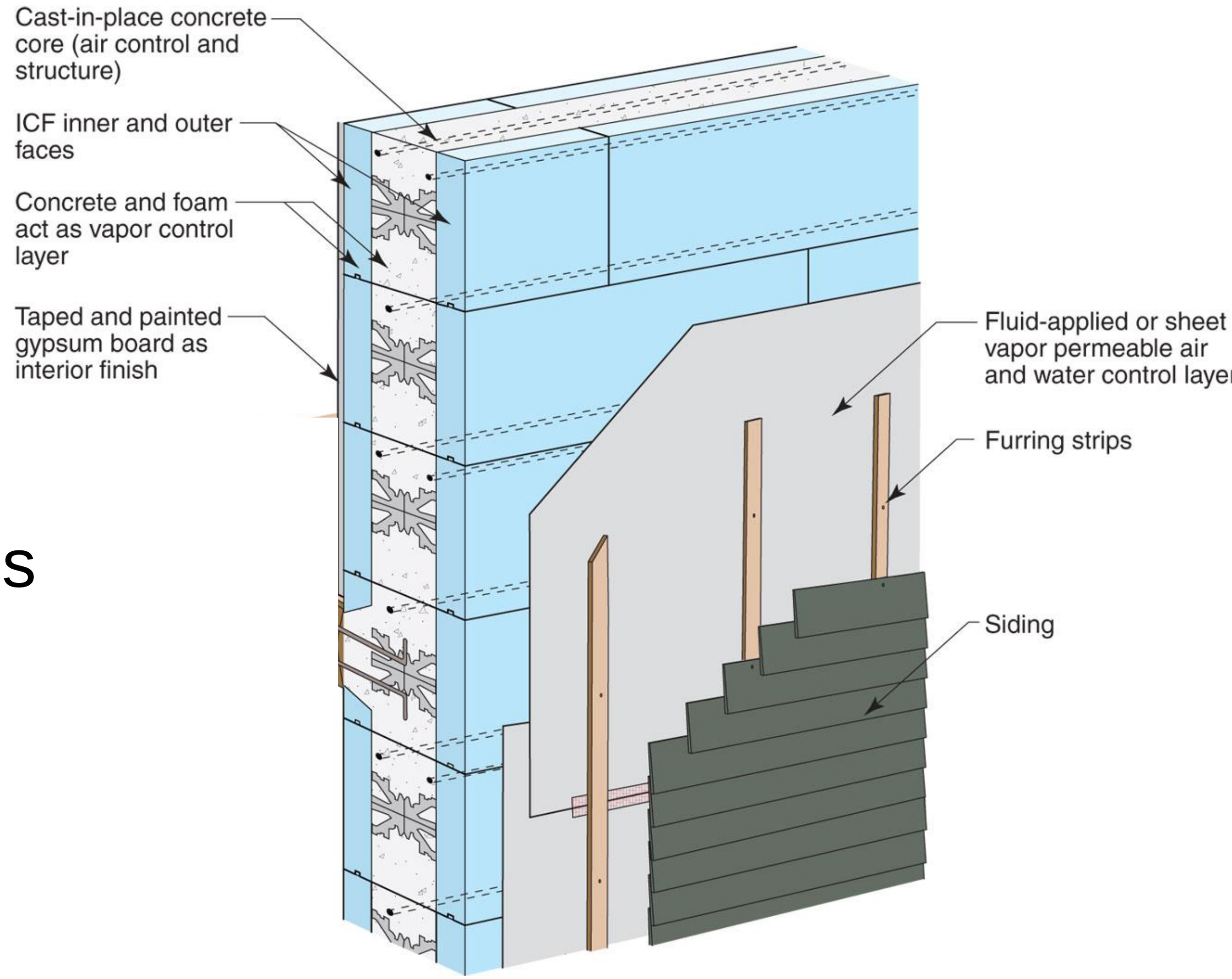


R-10 to R25

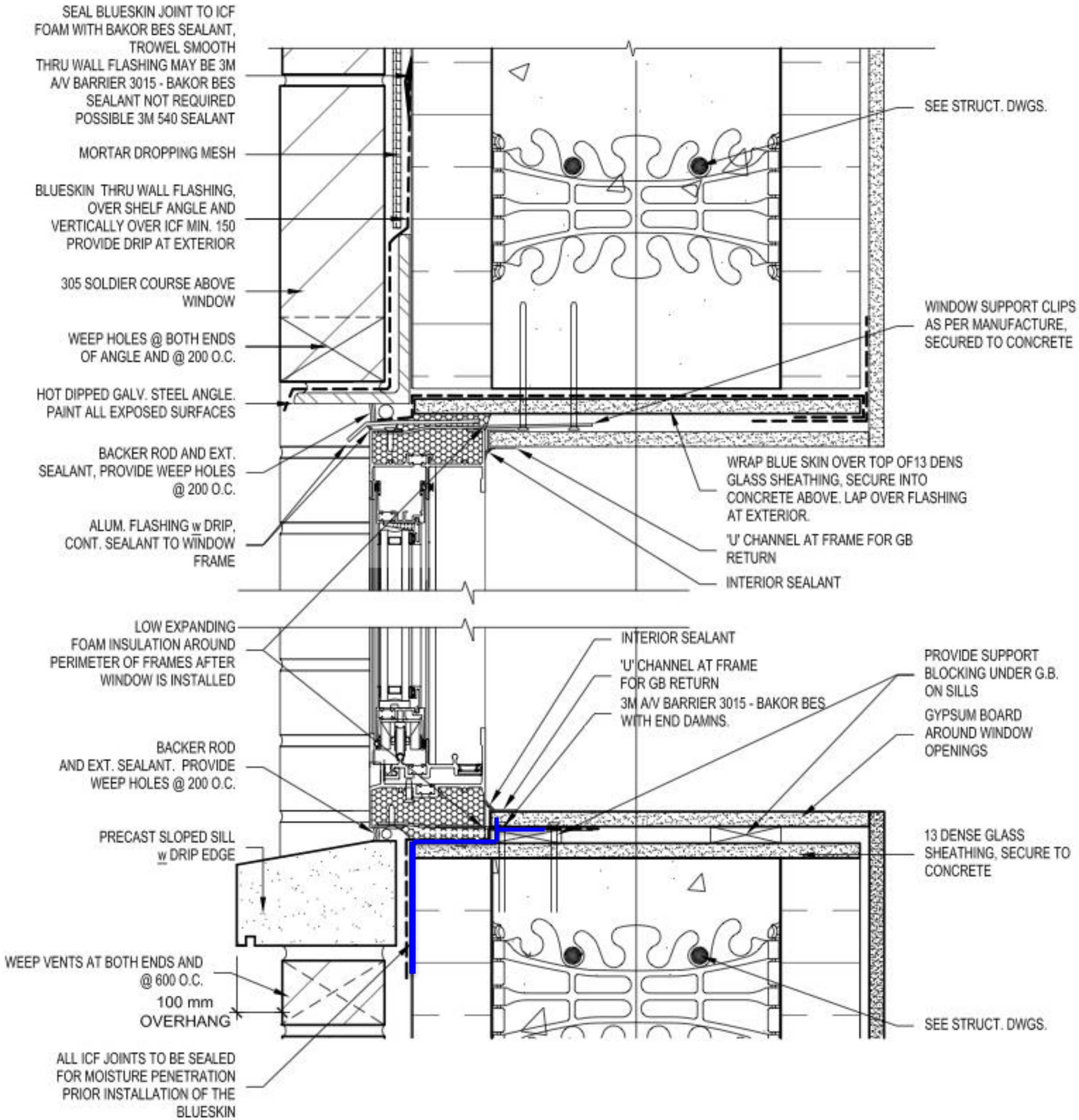
Fort McMurray, AB **Integrally Insulated** Wall Panels Windows Cast-in at Precast Plant

ICF & cladding

- Many options
- Drained is best but EIFS is practical
- Beware: all openings must be drained!

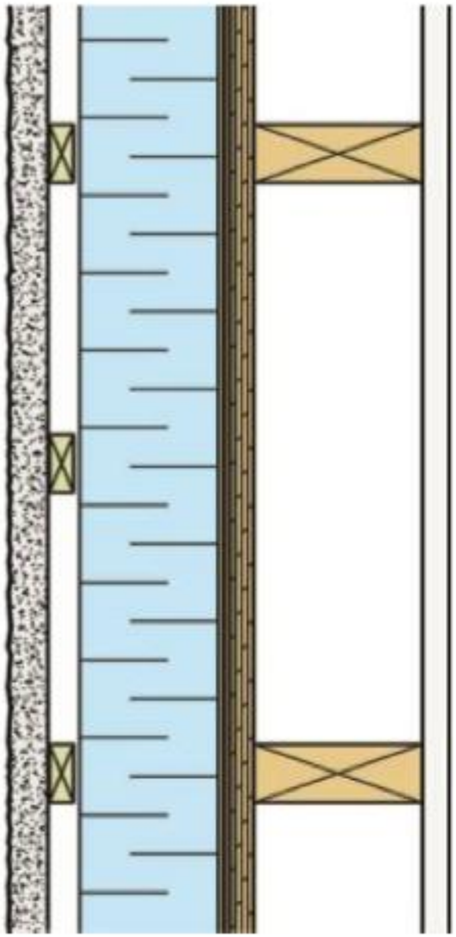


Window / Balcony Details are Critical! Drain opening.

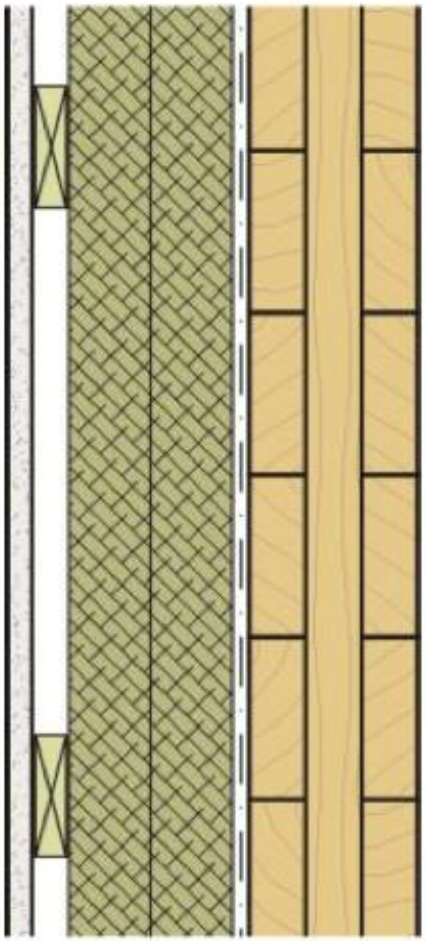

SEAL BLUESKIN JOINT TO ICF FOAM WITH BAKOR BES SEALANT, TROWEL SMOOTH
THRU WALL FLASHING MAY BE 3M A/V BARRIER 3015 - BAKOR BES SEALANT NOT REQUIRED POSSIBLE 3M 540 SEALANT
MORTAR DROPPING MESH
BLUESKIN THRU WALL FLASHING, OVER SHELF ANGLE AND VERTICALLY OVER ICF MIN. 150 PROVIDE DRIP AT EXTERIOR
305 SOLDIER COURSE ABOVE WINDOW
WEEP HOLES @ BOTH ENDS OF ANGLE AND @ 200 O.C.
HOT DIPPED GALV. STEEL ANGLE. PAINT ALL EXPOSED SURFACES
BACKER ROD AND EXT. SEALANT, PROVIDE WEEP HOLES @ 200 O.C.
ALUM. FLASHING w DRIP, CONT. SEALANT TO WINDOW FRAME
LOW EXPANDING FOAM INSULATION AROUND PERIMETER OF FRAMES AFTER WINDOW IS INSTALLED
BACKER ROD AND EXT. SEALANT. PROVIDE WEEP HOLES @ 200 O.C.
PRECAST SLOPED SILL w DRIP EDGE
WEEP VENTS AT BOTH ENDS AND @ 600 O.C.
100 mm OVERHANG
ALL ICF JOINTS TO BE SEALED FOR MOISTURE PENETRATION PRIOR INSTALLATION OF THE BLUESKIN
SEE STRUCT. DWGS.
WINDOW SUPPORT CLIPS AS PER MANUFACTURE, SECURED TO CONCRETE
WRAP BLUE SKIN OVER TOP OF13 DENS GLASS SHEATHING, SECURE INTO CONCRETE ABOVE. LAP OVER FLASHING AT EXTERIOR.
'U' CHANNEL AT FRAME FOR GB RETURN
INTERIOR SEALANT
INTERIOR SEALANT
'U' CHANNEL AT FRAME FOR GB RETURN
3M A/V BARRIER 3015 - BAKOR BES WITH END DAMNS.
PROVIDE SUPPORT BLOCKING UNDER G.B. ON SILLS
GYPSUM BOARD AROUND WINDOW OPENINGS
13 DENSE GLASS SHEATHING, SECURE TO CONCRETE
SEE STRUCT. DWGS.

- **Beware "stick and peels"**

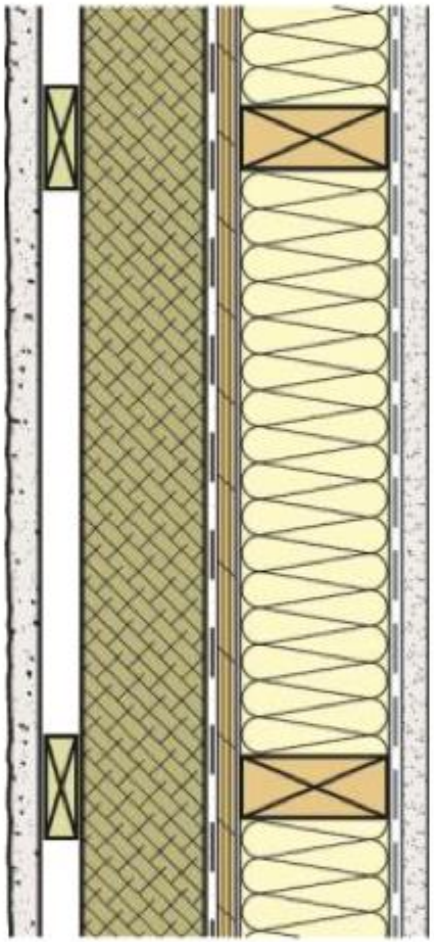
Wood Enclosure Options



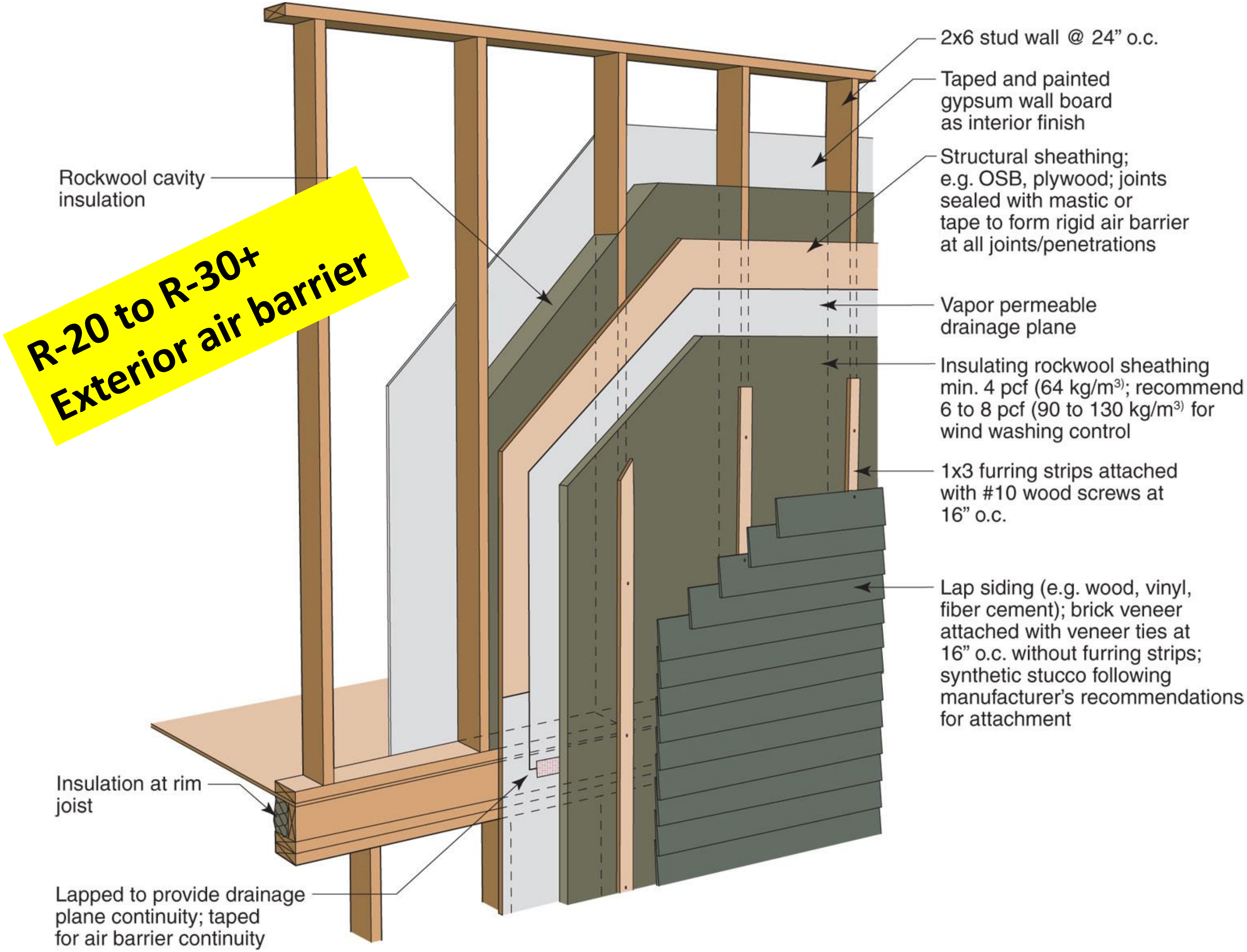
2x4 (or 2x6) stud wall



CLT/mass timber



2x4 (or 2x6) stud wall



R-20 to R-30+
Exterior air barrier
2x6 stud wall @ 24" o.c.
Taped and painted gypsum wall board as interior finish
Structural sheathing; e.g. OSB, plywood; joints sealed with mastic or tape to form rigid air barrier at all joints/penetrations
Vapor permeable drainage plane
Insulating rockwool sheathing min. 4 pcf (64 kg/m3); recommend 6 to 8 pcf (90 to 130 kg/m3) for wind washing control
1x3 furring strips attached with #10 wood screws at 16" o.c.
Lap siding (e.g. wood, vinyl, fiber cement); brick veneer attached with veneer ties at 16" o.c. without furring strips; synthetic stucco following manufacturer's recommendations for attachment
Rockwool cavity insulation
Insulation at rim joist
Lapped to provide drainage plane continuity; taped for air barrier continuity

Poor/Limited Choices

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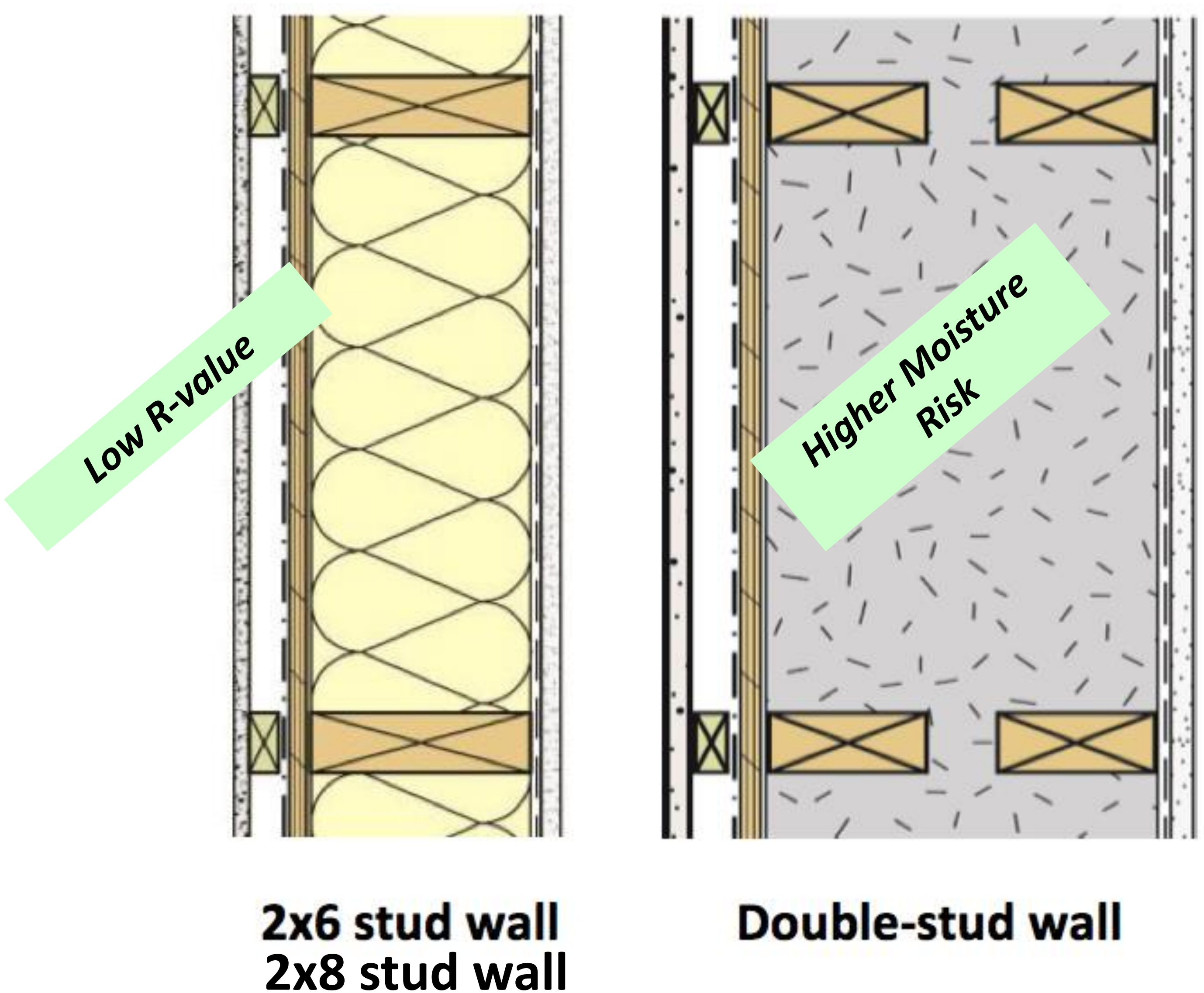

Conclusions

- Different material have different properties
- Different projects have different needs
- We can usually use all materials for all projects, but …
  the best materials will depend on the project!

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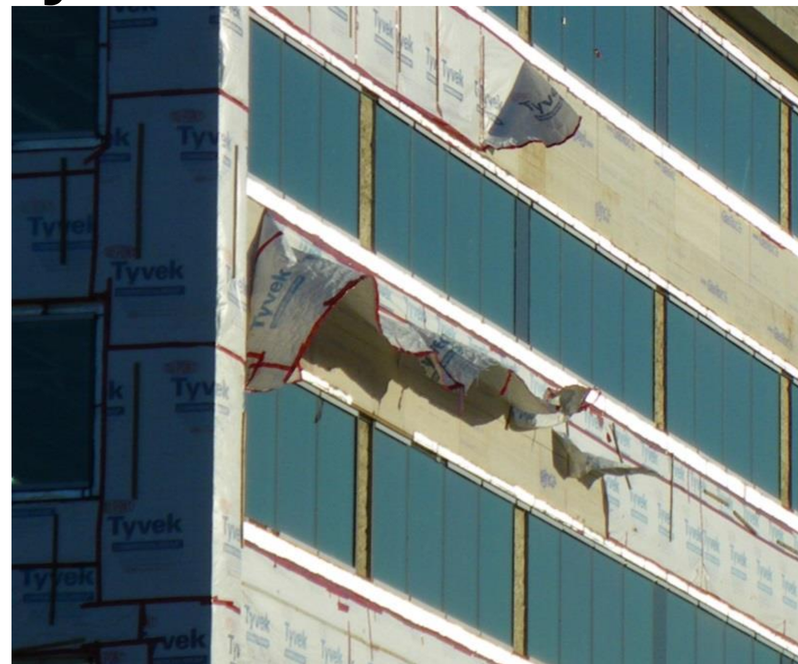
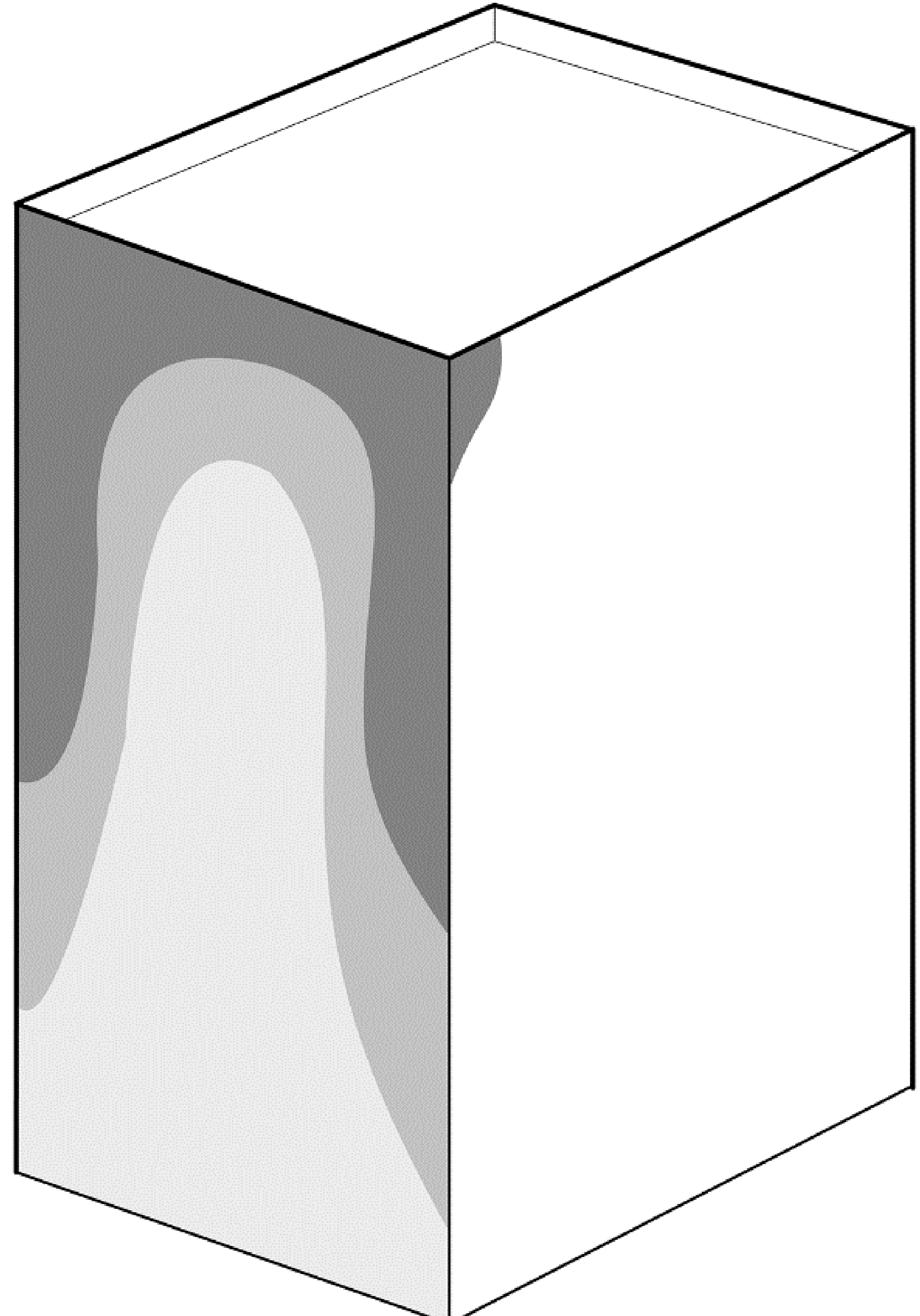
Challenges with Mechanically Attached Water Control Layer & Wind

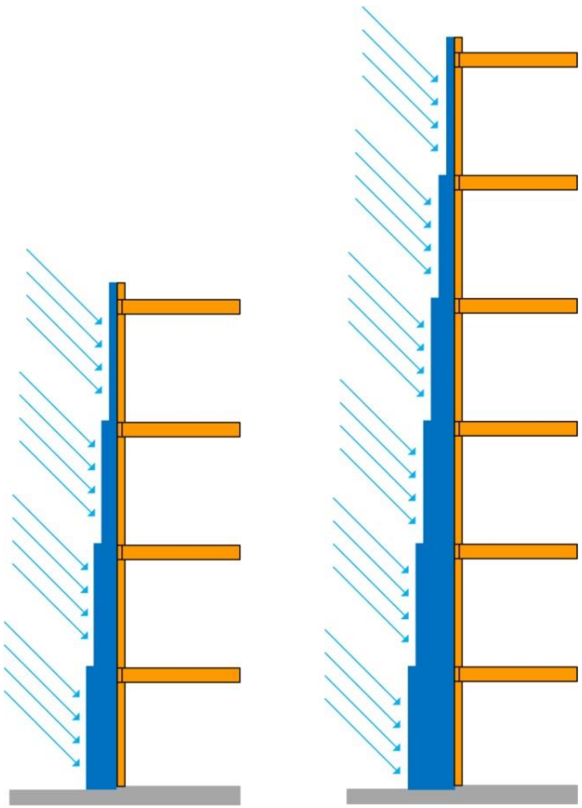


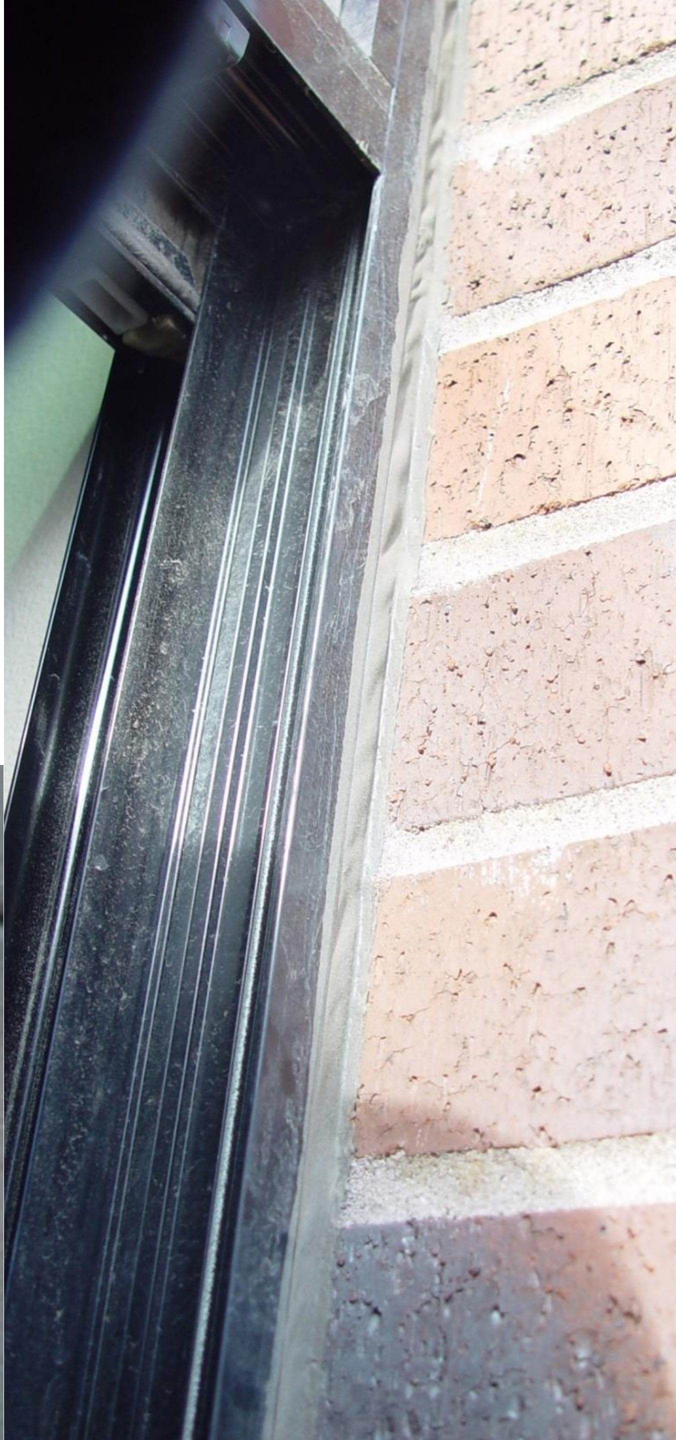
Fully-adhered air & water barriers preferred for higher exposure



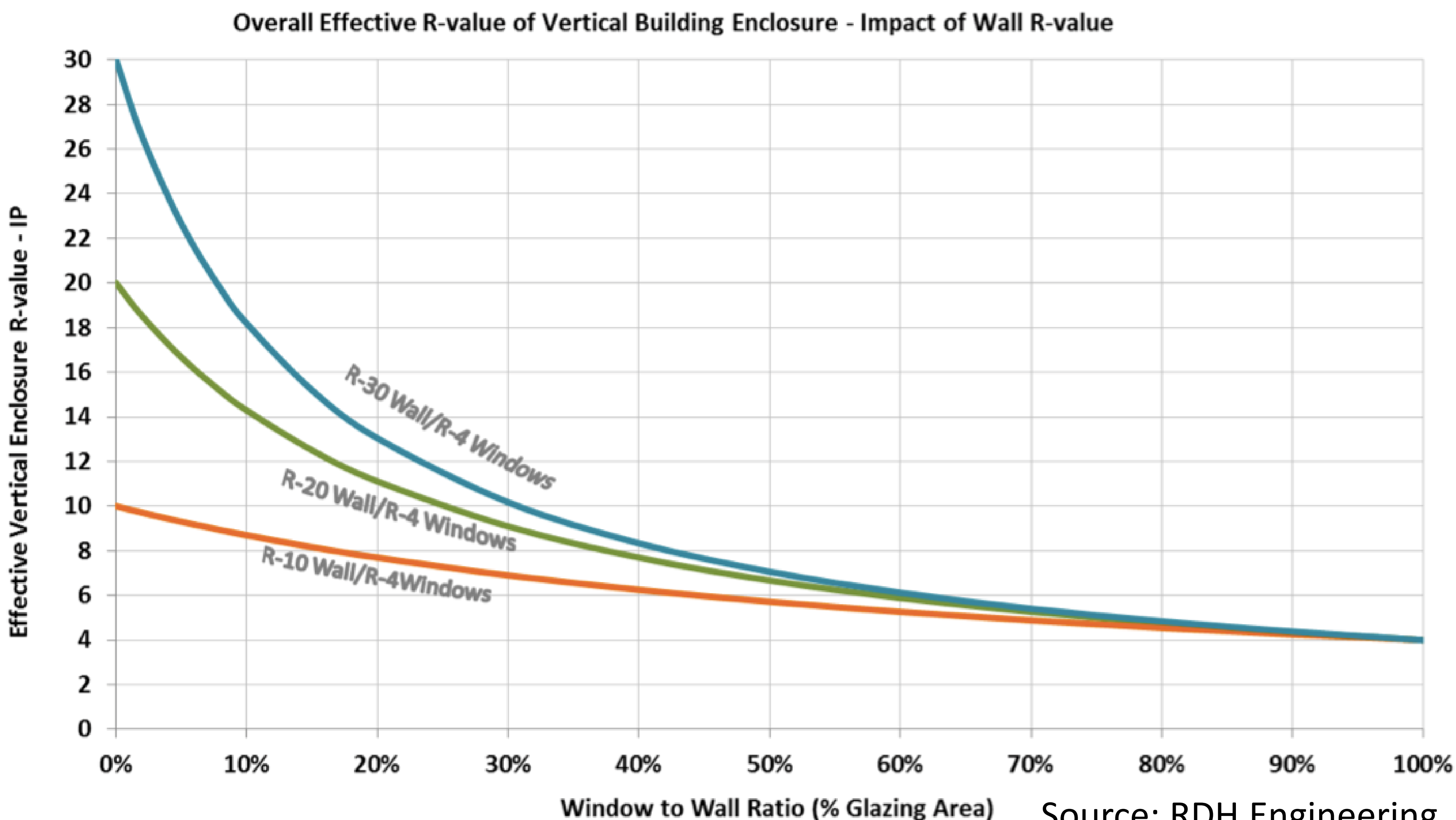
Increase in Wind and Rain Loads

- Specified structural and water penetration performance criteria for windows
  - Some low-rise windows may not work as well in mid-rise buildings
- Cumulative runoff
  - Water shedding features become more critical – continuity, drip edges
  - Water penetration control strategy
  - Selection of materials
- Moisture during longer construction period





Does Wall R-value Matter?



Source: RDH Engineering


S-45

Air-water barrier quality and durability?