Today's Presentation

Continuous Exterior Insulation: Design Considerations for Improved Durability and Energy Performance

M. Steven Doggett, Ph.D., LEED AP
Built Enviornments, Inc.

1 Background

1. Definitions
2. Compliance Paths
3. Historical Context

2 Design Considerations

1. Thermal Bridging
2. Moisture Control
3. Drainage Plane
4. Rainscreens

3 Case Studies

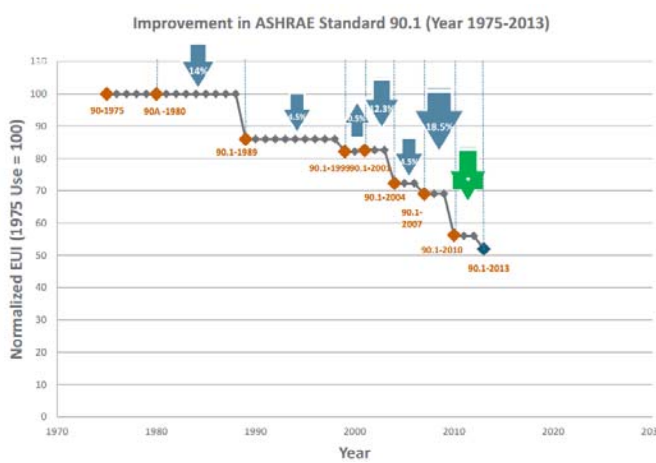
1. Rainscreen Airflows
2. Convective Heat Loss
3. Insulation Gaps

Please feel free to ask questions at any point in this presentation

Continuous Insulation

What is driving CI?

- Increasing stringency in energy codes
  - Goals
  - Prescriptive Paths
- Energy inefficiency of wall types
  - Wood frame: 10-20% reduction
  - Steel frame: 50-60% reduction
- Voluntary energy initiatives
  - Green Building Codes
  - LEED, GBI
  - Passive House

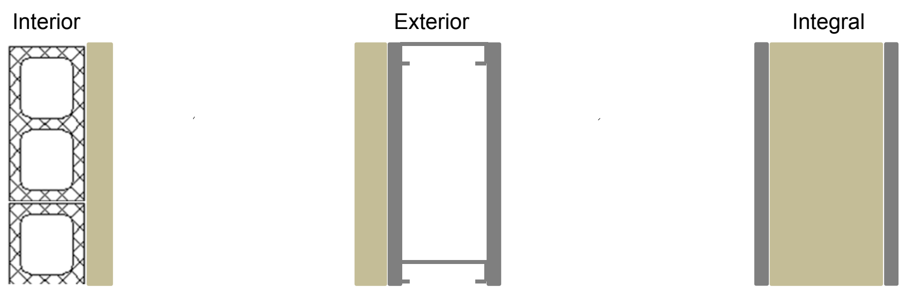


Pacific Northwest National Laboratory

Definition – ASHRAE 90.1 2010

Continuous Insulation

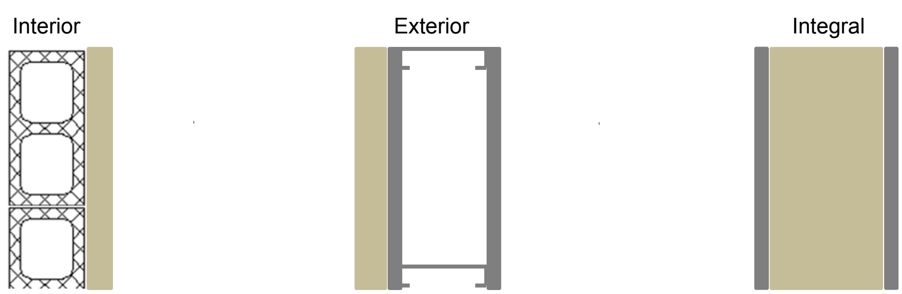
"Insulation that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior, exterior or is integral to any opaque surface of the building envelope."



Definition – Minnesota 1323.0020

Continuous Insulation

"Insulation that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior, exterior or is integral to any opaque surface of the building ***thermal*** *envelope."*



Definition – Minnesota 1323.0020

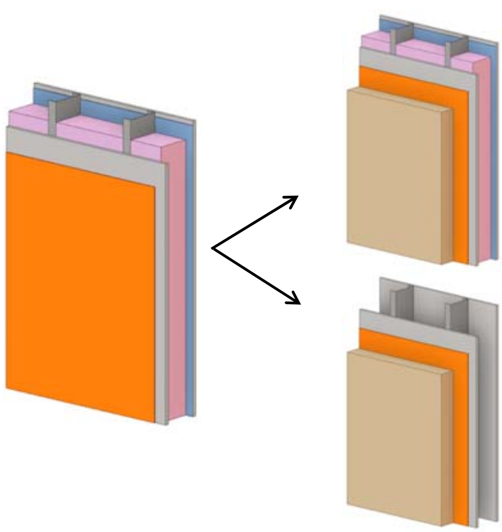
Continuous Insulation

*"Insulation that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior, exterior or is integral to any opaque surface of the building **thermal** envelope."*

Key Considerations for MN: Cladding Attachment Systems

- Cladding attachment systems are not explicitly addressed
- MN enforcement is not necessarily addressing thermal bridging by cladding attachment systems
- Life & Safety may supersede prescriptive R value requirements
- **Enforcement relies on the opinion of the design professional**

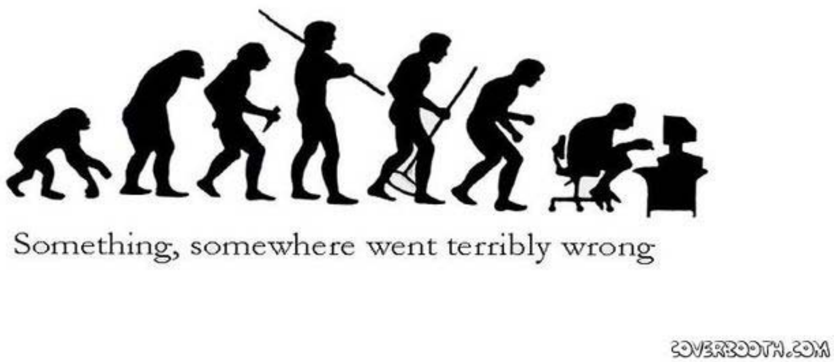
CI: A Fundamental Departure



The Consequence of Change

1. Reduced thermal bridging
2. Altered air permeability
3. Altered vapor permeability
4. Dual drainage plane
5. Isolation of drainage plane from rainscreen
6. Thermally buffered wall sheathing
7. Altered moisture transport paths/rates
8. Increased complexity

CI: A Fundamental Departure



Historical Context

Late 1930's &1940's
Emergence of Recognized Moisture Problems
Birth of 'Building Science'

Late 1940's
Modern Rainscreens

1970's
Energy Codes & Use of Vapor Barriers

1980's
Failures in Buildings clad with EIFS

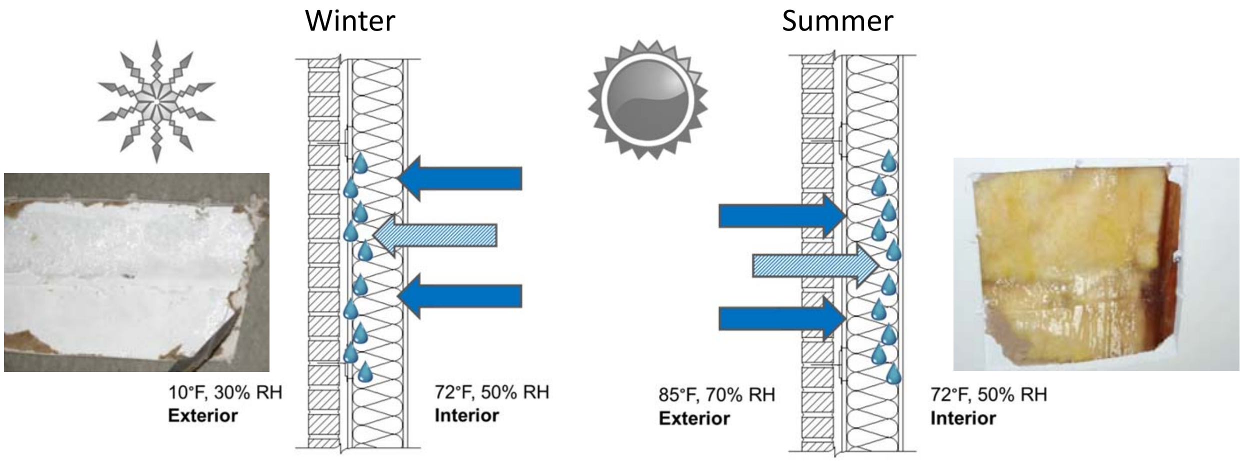
1990's
North American Building Failures

2000's
Failures in 'Corrected' Buildings

2004
Emergence of CI Requirements

2010 & 2012
CI Acceptance Widens

Historical Context



Historical Context

‘Doctrines for Moisture Control’
1994 ASTM MNL 18: Moisture Control in Buildings

- The building will not leak.
- The building will not allow the accumulation of water where the building may be adversely affected.
- The building will not be unduly affected by predictable influx of moisture in the physical construction.
- The building will expel water which enters into the construction predictably.
- The building will not utilize materials that entrap excessive amounts of water under predictable circumstances.

Historical Context

'Doctrines for Moisture Control'
3 Important Points

1. **Perhaps all moisture-related problems could be prevented.**
2. **Instead, moisture-related problems remain the primary cause of building failures.**
3. **CI mandates have further complicated these flawed practices.**

Design Considerations

The Human Factor

- Design & construction processes are imperfect.
- Manufactured systems are imperfect.
- New performance standards create new challenges.
- High maintenance objectives are rarely achieved.
- Humans like to re-purpose buildings.

The Climate Factor

- Reasonable climate extremes are not addressed.
- Design assumptions for water entry are inadequate.

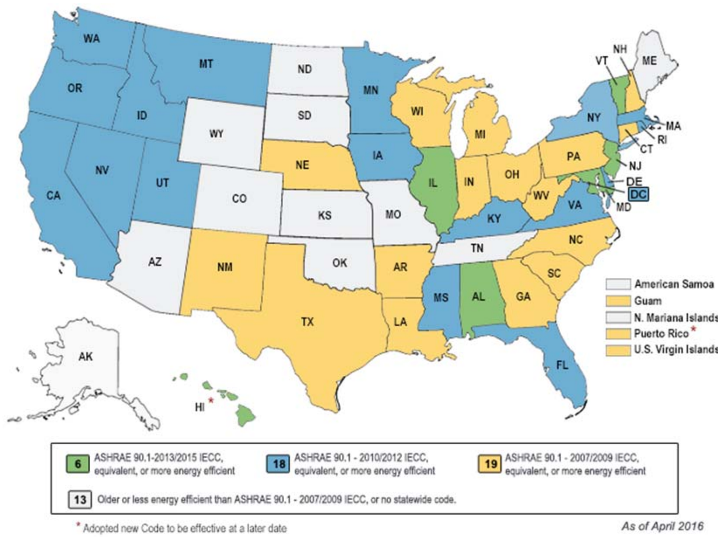
Commercial Code Adoption – June 2016

Minnesota

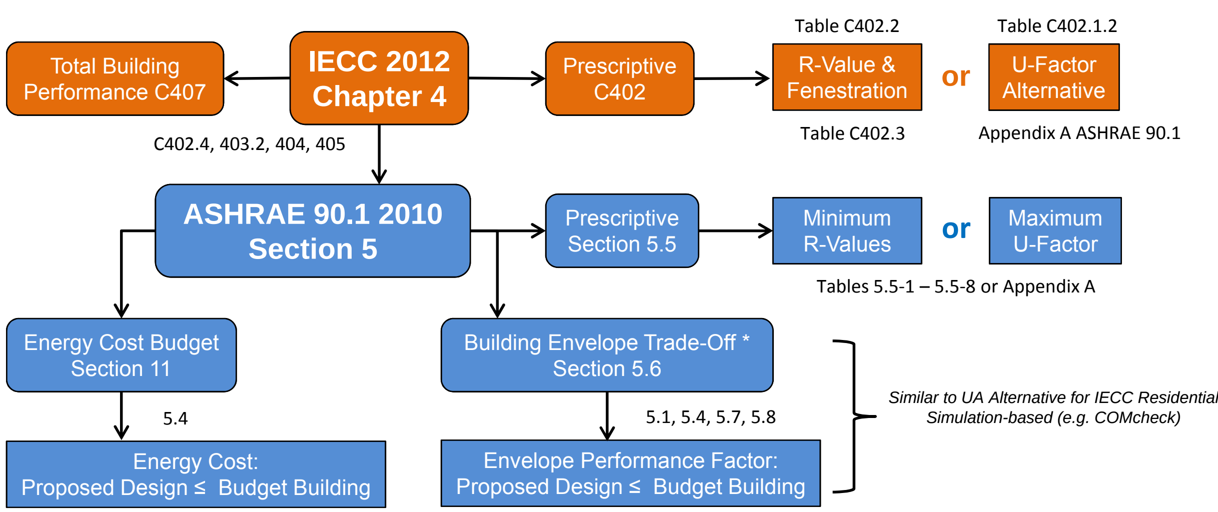
2012 International Energy Conservation Code

(with amendments)

Adopted June 2, 2015

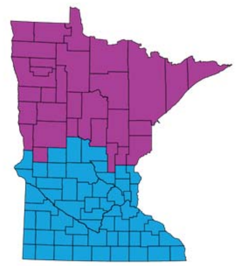


Building Envelope Compliance Paths

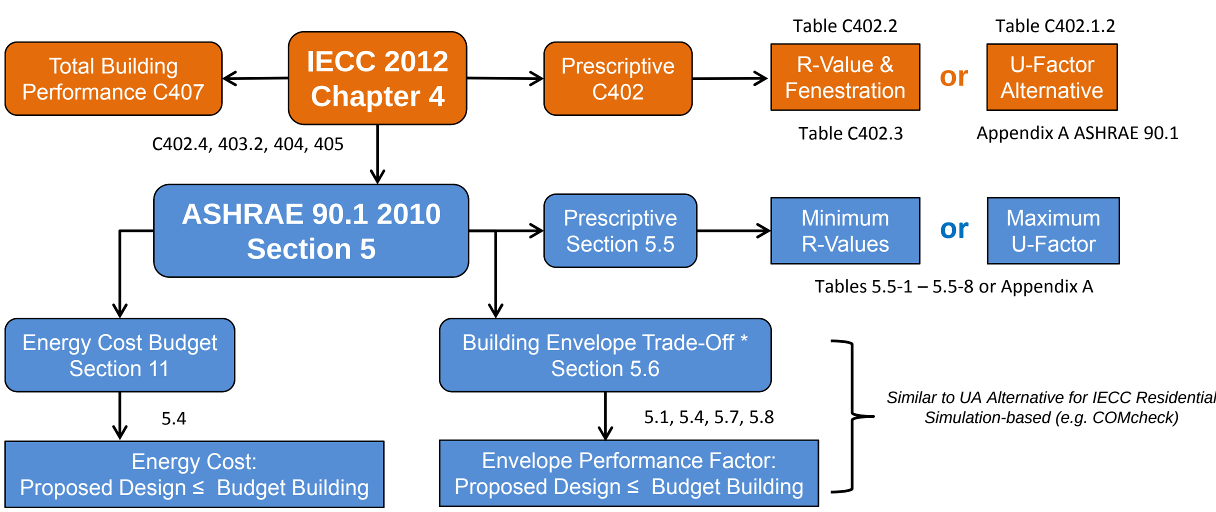


IECC 2012: Table C402.2

CLIMATE ZONE	1		2		3		4 EXCEPT MARINE		5 AND MARINE 4		6		7		8	
	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R
Walls, Above Grade																
Mass	R-5.7ci	R-5.7ci	R-5.7ci	R-7.6ci	R-7.6ci	R-9.5ci	R-9.5ci	R-11.4ci	R-11.4ci	R-13.3ci	R-13.3ci	R-15.2ci	R-15.2ci	R-15.2ci	R-25ci	R-25ci
Metal building	R-13+ R-6.5ci	R-13 + R-6.5ci	R13 + R-6.5ci	R-13 + R-13ci	R-13 + R-6.5ci	R-13 + R-13ci	R-13 + R-13ci	R-13 + R-13ci	R-13 + R-13ci	R-13 + R-13ci	R-13+ R-13ci	R-13 + R-13ci	R-13 + R-13ci	R-13+ R-19.5ci	R-13 + R-13ci	R-13+ R-19.5ci
Metal framed	R-13 + R-5ci	R-13 + R-5ci	R-13 + R-5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-15.6ci	R-13 + R-7.5ci	R-13+ R17.5ci
Wood framed and other	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-15.6ci or R-20 + R-10ci	R-13 + R-15.6ci or R-20 + R-10ci

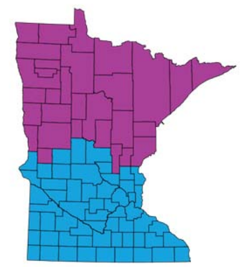


Building Envelope Compliance Paths

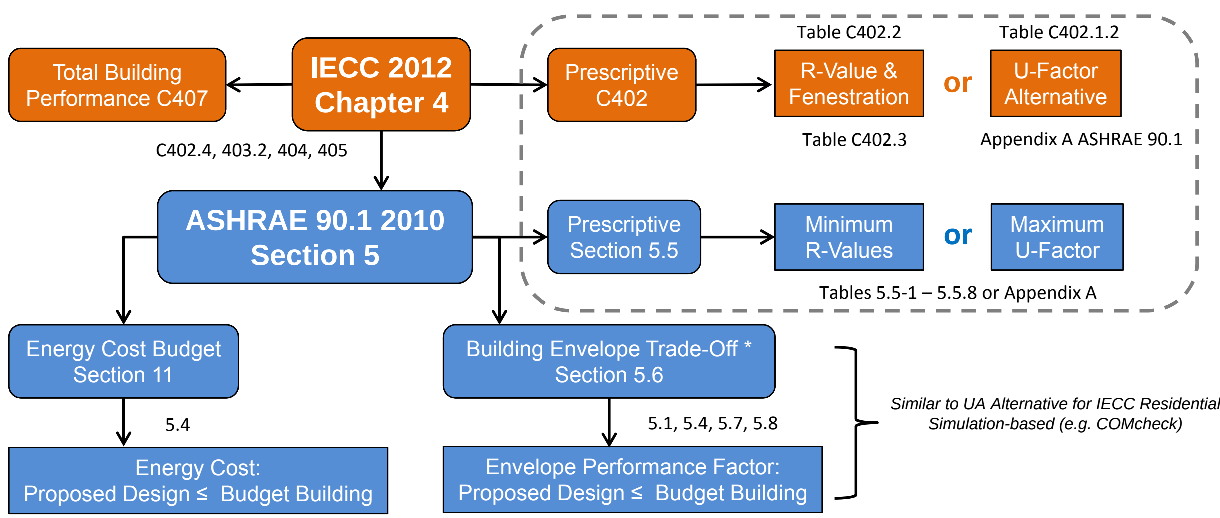


IECC 2012: Table C402.1.2

CLIMATE ZONE	1		2		3		4 EXCEPT MARINE		5 AND MARINE 4		6		7		8	
	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R
Walls, Above Grade																
Mass	U-0.142	U-0.142	U-0.142	U-0.123	U-0.110	U-0.104	U-0.104	U-0.090	U-0.078	U-0.078	U-0.078	U-0.071	U-0.061	U-0.061	U-0.061	U-0.061
Metal building	U-0.079	U-0.079	U-0.079	U-0.079	U-0.079	U-0.052	U-0.052	U-0.052	U-0.052	U-0.052	U-0.052	U-0.052	U-0.052	U-0.039	U-0.052	U-0.039
Metal framed	U-0.077	U-0.077	U-0.077	U-0.064	U-0.064	U-0.064	U-0.064	U-0.064	U-0.064	U-0.064	U-0.064	U-0.057	U-0.064	U-0.052	U-0.045	U-0.045
Wood framed and other	U-0.064	U-0.064	U-0.064	U-0.064	U-0.064	U-0.064	U-0.064	U-0.064	U-0.064	U-0.064	U-0.051	U-0.051	U-0.051	U-0.051	U-0.036	U-0.036



Building Envelope Compliance Paths



Building Envelope: Prescriptive Design

Continuous Insulation – Steel Frame

- Required for all climate zones

- Not required for climate zones 1 and 2

Building Envelope: Prescriptive Design

Air Barrier

- Continuous Air Barrier: air permeability no greater than 0.004 cfm/ft^2 (0.02 L/s • m^2) under a pressure differential of 0.3 inches water gauge (w.g.) (75 Pa) when tested in accordance with ASTM E 2178

- Assemblies of materials and components with an average air leakage not to exceed 0.04 cfm/ft^2 (0.2 L/s • m^2) under a pressure differential of 0.3 inches of water gauge (w.g.)(75 Pa) when tested in accordance with ASTM E 2357, ASTM E 1677 or ASTM E 283

- The completed building shall be tested and the air leakage rate of the *building envelope* shall not exceed 0.40 cfm/ft^2 at a pressure differential of 0.3 inches water gauge (2.0 L/s • m^2 at 75 Pa) in accordance with ASTM E 779 or an equivalent method approved by the code official.

- The air leakage of fenestration assemblies shall meet the provisions of Table C402.4.3. or Section 5.4.3.2 in ASHRAE 90.1 2010

- Exception: Air barriers are not required in buildings located in Climate Zones 1, 2 and 3.
- **Additional exceptions**

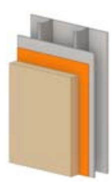
Building Envelope: Prescriptive Design

Considerations & Limitations

1. Most straightforward, but not always the most cost-effective.
2. Costs are driving alternative compliance options.
3. Assembly U-factors for common wall types are available (e.g. Table A3.3 – ASHRAE 90.1 2010). These factors may not be accurate as desired for a specific wall type.
4. The effects of thermal bridging are not addressed.
5. Considerations for moisture performance are not addressed.
6. Must still consider NFPA 285 compliance (fire propagation).

Prescriptive Strategies

Exterior CI



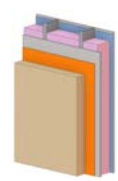
Advantages

- Improved energy efficiency
- Improved moisture performance
- Potential cost reductions

Disadvantages

- Cladding attachment considerations
- Dual drainage plane
- Lacks historical precedence regarding performance for varied assemblies

Hybrid



Advantages

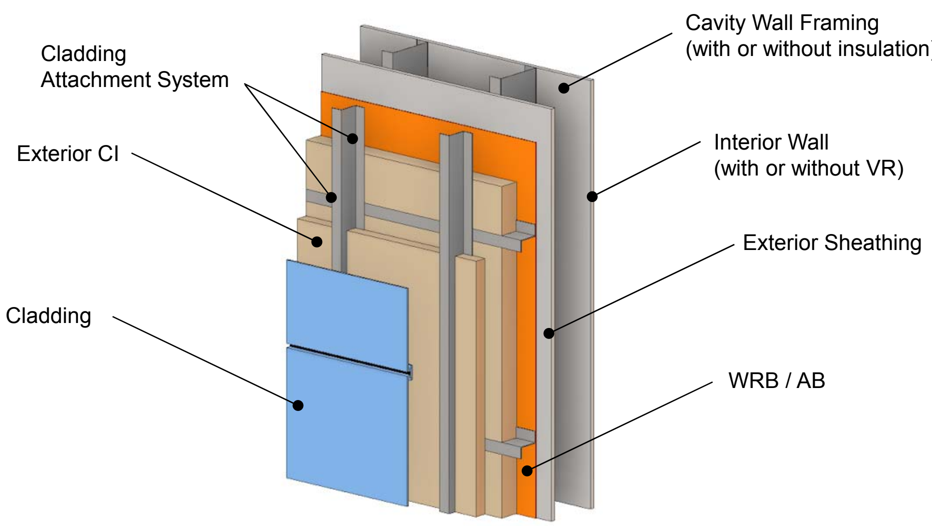
- Even higher energy efficiency
- Potential cost reduction for cladding attachment

Disadvantages

Same as Exterior CI, plus:

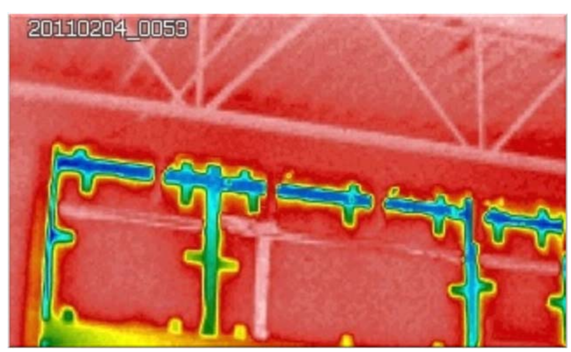
- Considerations for interior VR
- Higher potential for hygrothermal problems

Prescriptive Strategies



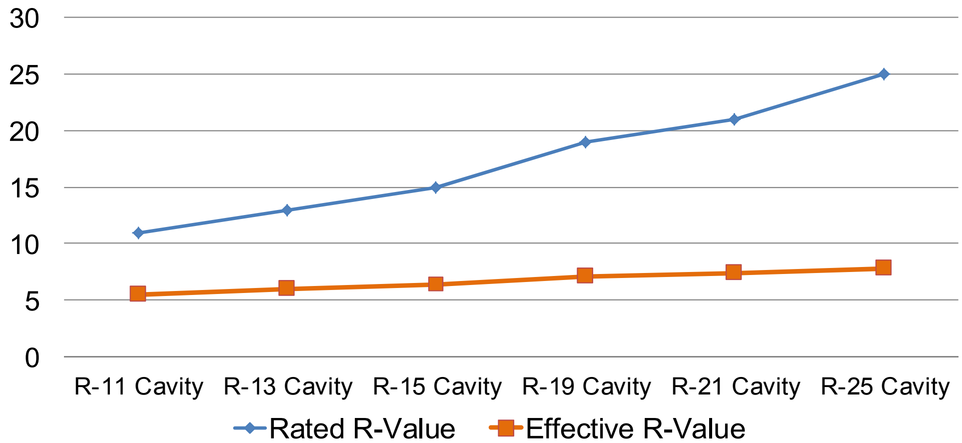
Design Considerations

Thermal Bridging

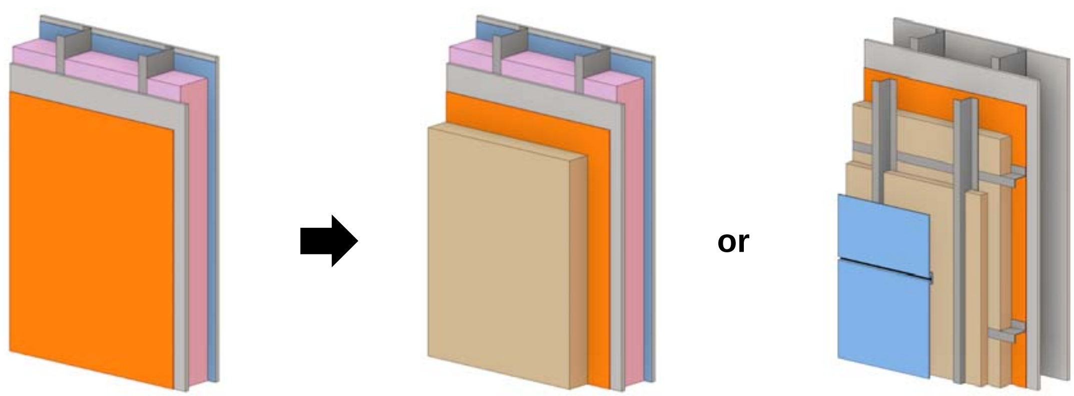


Design Considerations: Thermal Bridging

Effective R-value of Cavity Insulation in Steel Framed Walls – ASHRAE 90.1 Table A9.2B



Design Considerations: Thermal Bridging



Conventional Wall

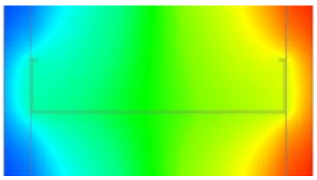
1 Cavity Framing

2 Framing + Cladding Attachments

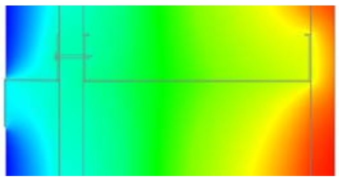
Design Considerations: Thermal Bridging

Basic Insulation Strategies

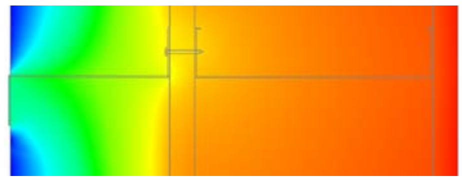
Conventional Wall



Hybrid Wall



Exterior CI Wall



- Unmitigated Bridging
- Unconditioned Sheathing
- Low Drying Potential

- Reduced Bridging
- Semi-Conditioned Sheathing
- Low Drying Potential

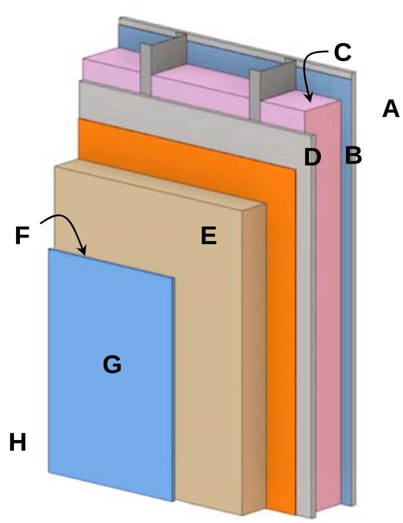
- No Appreciable Bridging
- Conditioned Sheathing
- High Drying Potential

Design Considerations: Thermal Bridging

Wall Cavities with Insulation

ASHRAE 90.1 2010
Table A9.2B – Steel Frame

R-value of cavity insulation is reduced for metal studs and wall depth at 16" and 24" spacing.



A. Interior Air Film	0.68
B. 5/8" Gypsum Board	0.56
C. 4" Cavity R-13 (16" oc)	6.0
D. 5/8" Gypsum Board	0.56
E. Ext. Insulation (1.5" polyiso)	9.18
F. Air Space (Table A9.4A)	1
G. Cladding	0.59
H. Exterior Air Film	0.17
TOTAL	**18.74**

$U_W = 1 / [R_s + R_c]$
$1 / [12.74 + 6.0] = 1 / 18.74 = 0.53 < 0.64$

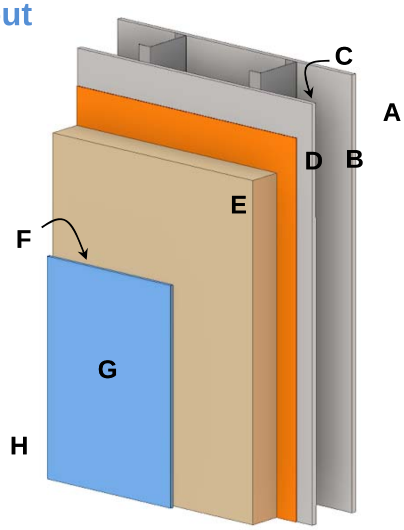
R_s = R value of wall elements, excluding framing
R_c = R value of insulation filled wall cavity

Design Considerations: Thermal Bridging

Wall Cavities without Insulation

ASHRAE 90.1 2010
Table A9.2B – Steel Frame

R-value of empty air space is either 0.79 (16" on center) or 0.91 (24" on center).



A. Interior Air Film	0.68
B. 5/8" Gypsum Board	0.56
C. 6" Cavity Air Space (16" oc)	0.79
D. 5/8" Gypsum Board	0.56
E. Ext. Insulation (2.5" polyiso)	15.3
F. Air Space	1
G. Cladding	0.59
H. Exterior Air Film	0.17
TOTAL	**19.65**

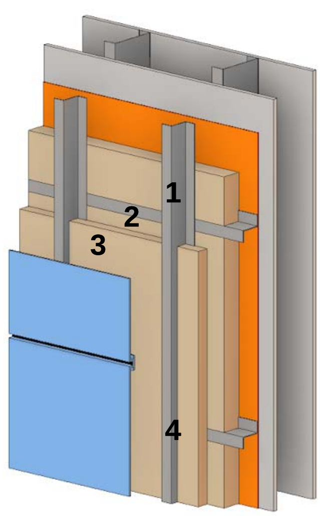
$U_W = 1 / [R_s + R_e]$
$1 / [18.86 + 0.79] = 1 / 19.65 = 0.51 < 0.64$

R_s = R value of wall elements, excluding framing
R_e = R value of empty wall cavity

Design Considerations: Thermal Bridging

Wall Cavities with Cladding Attachment

Assemblies have materials & regions with very different thermal resistances



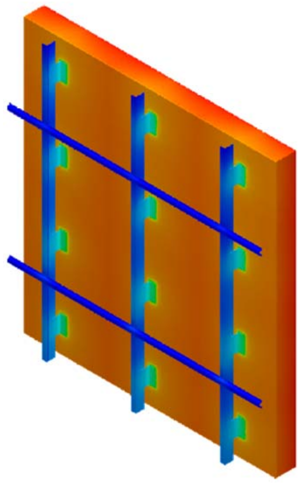
Specific calculations or assembly testing required

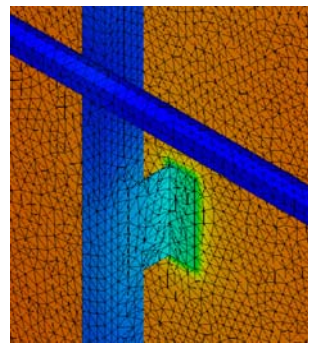
- Parallel Path
- Isothermal Path
- Zone Method
- Modified Zone Method
- Finite Element Analysis
- Wall Assembly Testing

Design Considerations: Thermal Bridging

Finite Element Analysis – a mathematical simulation for predicting how a product or assembly reacts to real-world forces, vibration, heat, fluid flow, and other physical effects.

Analyses are conveyed on three-dimensional tetrahedral meshes.

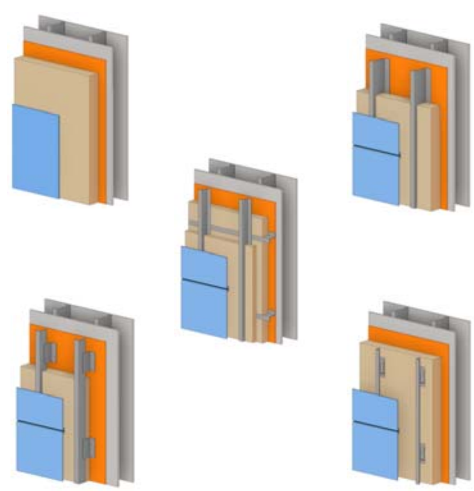




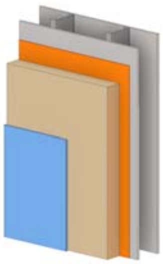
Design Considerations: Thermal Bridging

FEI Example

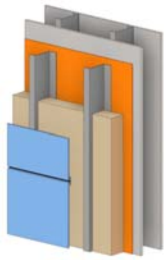
- Five wall types
- 4" exterior mineral wool
- No cavity insulation
- Dimensions: 2.6' w x 4' h
- Exterior: 23°F, Interior: 69.8°F
- Steady-state heat transfer
- Autodesk CFD 2016



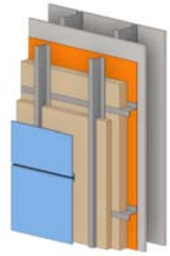
Design Considerations: Thermal Bridging



No Cladding Attachment

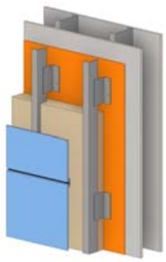


Vertical Girts

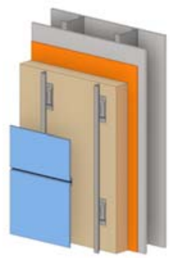


Double Girts

Brackets & Rails

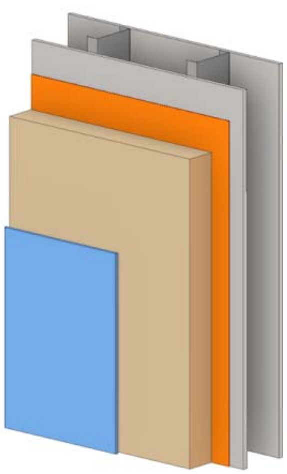


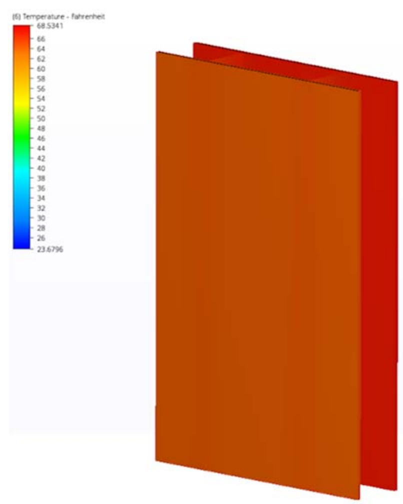
CI Bracket System



Design Considerations: Thermal Bridging

Nominal R
20.5





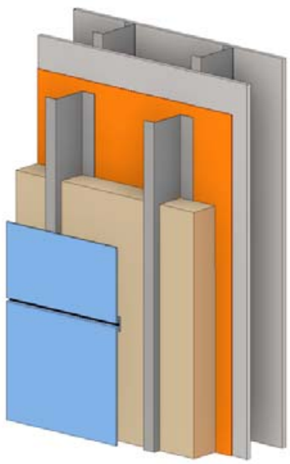
Effective R
20.5

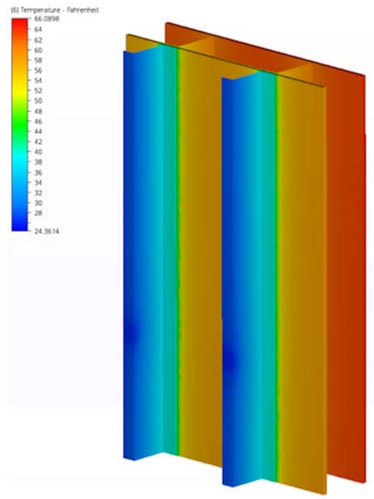
(excludes fasteners)

Reduction
-0%

Design Considerations: Thermal Bridging

Nominal R
20.5



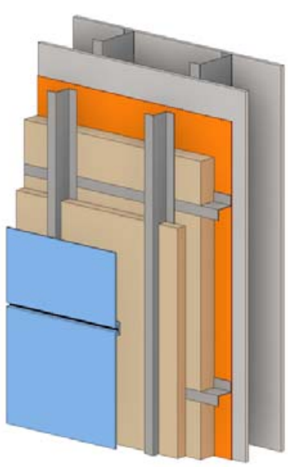


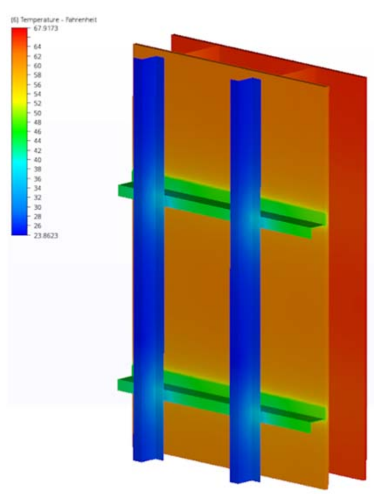
Effective R
7.6
(excludes fasteners)

Reduction
-63%

Design Considerations: Thermal Bridging

Nominal R
20.5



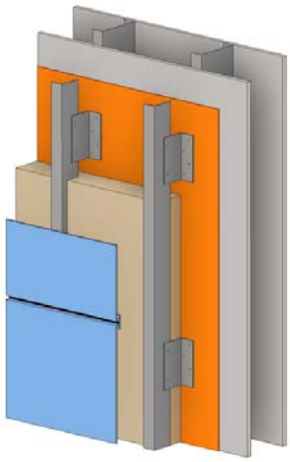


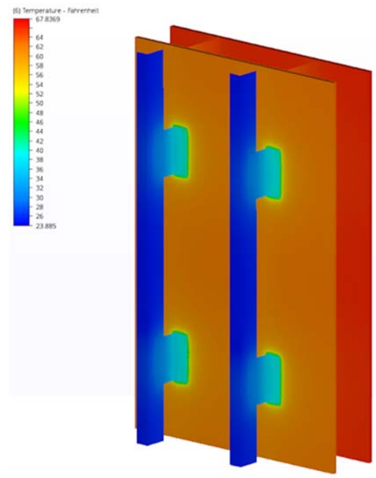
Effective R
12.2
(excludes fasteners)

Reduction
-41%

Design Considerations: Thermal Bridging

Nominal R
20.5



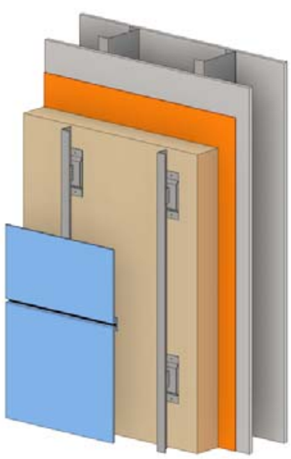


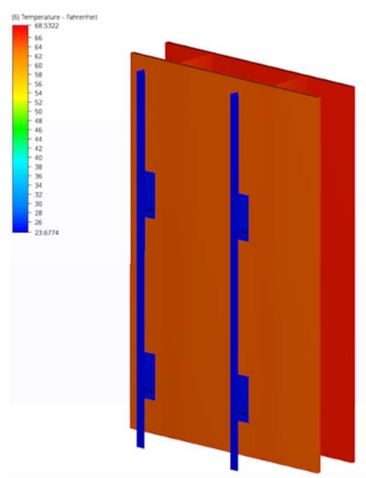
Effective R
12.7
(excludes fasteners)

Reduction
-38%

Design Considerations: Thermal Bridging

Nominal R
20.7





Effective R
20.6
(excludes fasteners)

Reduction
-0.5%

Design Considerations

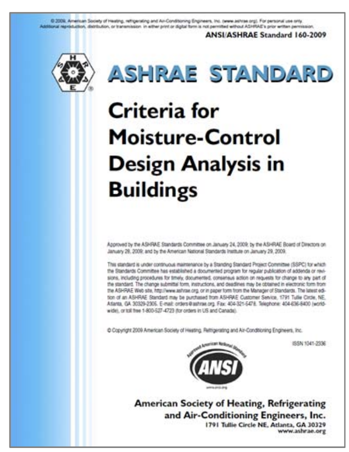
Moisture Control Design

Design Considerations: Moisture Control

ASHRAE 160-2009

The purpose of this standard is to specify performance-based design criteria for predicting, mitigating, or reducing moisture damage to the building envelope, materials, components, systems, and furnishings, depending on climate, construction type, and HVAC system operation. These criteria include:

a. Criteria for selecting analytical procedures
b. Criteria for inputs
c. Criteria for evaluation and use of inputs



© 2009, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (www.ashrae.org). For personal use only. Additional reproduction, distribution, or transmission in either print or digital form is not permitted without ASHRAE's prior written permission.

ANSI/ASHRAE Standard 160-2009

ASHRAE STANDARD

Criteria for Moisture-Control Design Analysis in Buildings

Approved by the ASHRAE Standards Committee on January 24, 2009; by the ASHRAE Board of Directors on January 28, 2009; and by the American National Standards Institute on January 29, 2009.

This standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE Web site, http://www.ashrae.org, or in paper form from the Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 404-321-5478. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada).

© Copyright 2009 American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

ISSN 1041-2336

ANSI

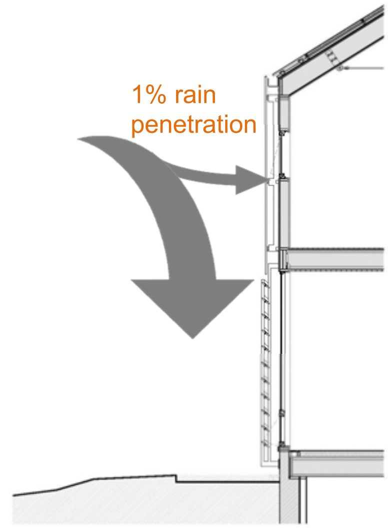
American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
1791 Tullie Circle NE, Atlanta, GA 30329
www.ashrae.org

Design Considerations: Moisture Control

ASHRAE 160: Rainwater Penetration

In the absence of specific full-scale test methods and data for the as-built exterior wall system being considered, the default value for water penetration through the exterior surface shall be 1% of the water reaching that exterior surface.

The deposit site for the water shall be the exterior surface of the water-resistive barrier. If a water-resistive barrier is not provided, then the deposit site shall be described and a technical rationale for its location shall be provided.



Design Considerations: Moisture Control

ASHRAE 160: Evaluation Criteria

Running Average Surface RH	Running Average Temperature	Period (days)
<80	41°F - 104°F	30
<98	41°F - 104°F	7
<100	41°F - 104°F	1

Conditions Necessary to Minimize Mold Growth
Conditions Necessary for Prevention of Corrosion

Design Considerations: Moisture Control

ASHRAE 160 Evaluation Criteria

These criteria apply to all materials and surfaces except the exterior of the building envelope.

Materials that are naturally resistant to mold or have been chemically treated to resist mold growth may be able to resist higher surface relative humidities and/or resist for longer periods as specified by the manufacturer.

ASTM G-21: Synthetic Polymerics: PVCs and Plastics
ASTM C-1338: Insulation & Facings
ASTM D-3273, ASTM D-5590: Paints & Coatings

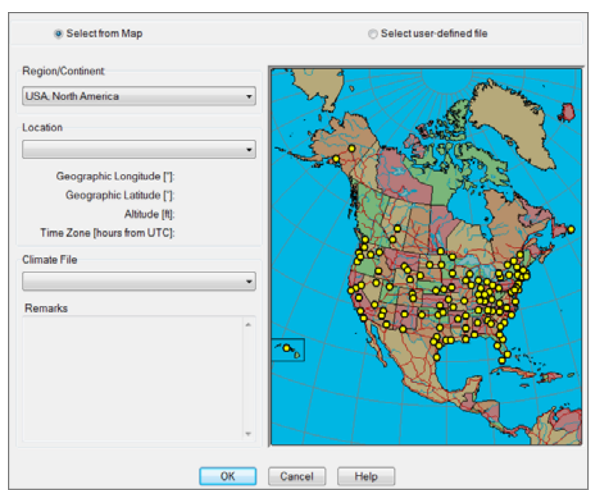
Design Considerations: Moisture Control

WUFI®

Wärme- Und Feuchtetransport Instationär - Transient heat and moisture transport.

Climate Data Files

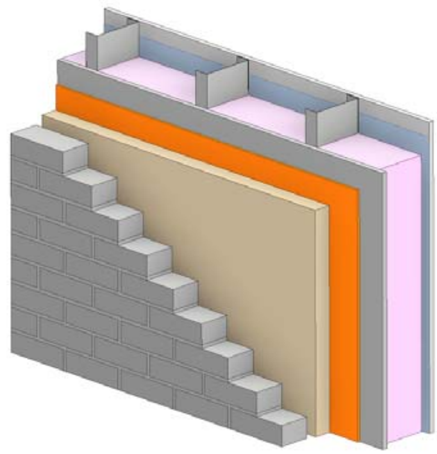
- Warm Year / Cold Year
- ASHRAE Weather Years (RP1325) Moisture Design Reference Years
    - Year 1 – most severe
    - Year 2
    - Year 3 – least severe



Design Considerations: Moisture Control

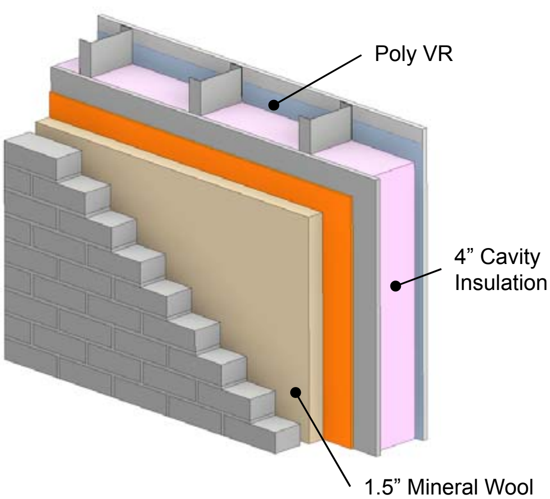
Hygrothermal Examples

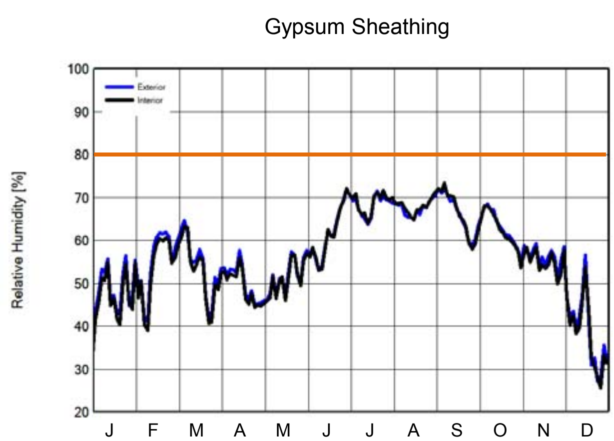
- Brick-clad wall
- Continuous ventilated air space: 5 ACH
- Various insulation strategies
- Varied configurations: WRB and VR
- Climate: Minneapolis, Minnesota
- ASHRAE Year 1
- Monitor RH at exterior and interior surfaces of gypsum sheathing



Design Considerations: Moisture Control

R 20.5



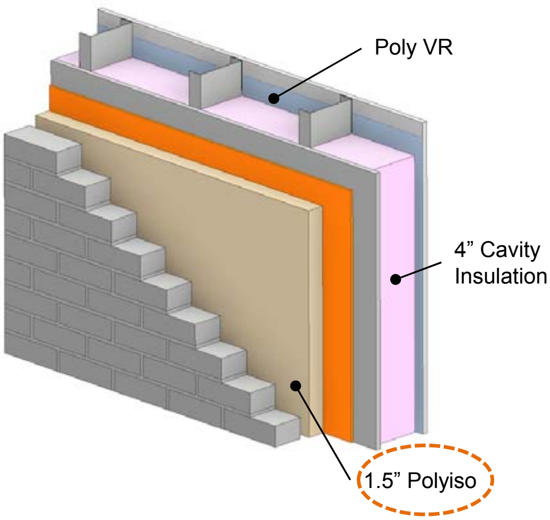


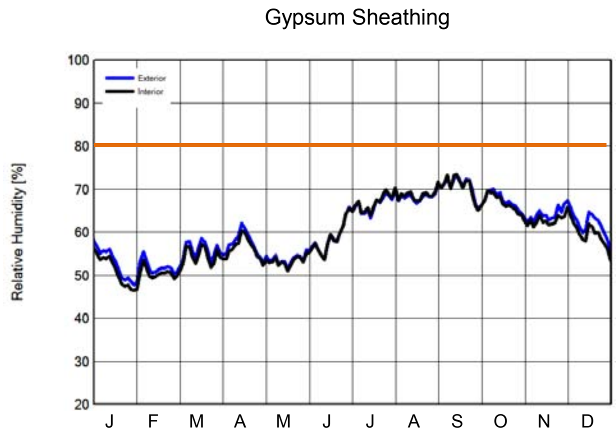
Minneapolis, Minnesota

Design Considerations: Moisture Control

R 20.5

Insulation Type: Polyiso





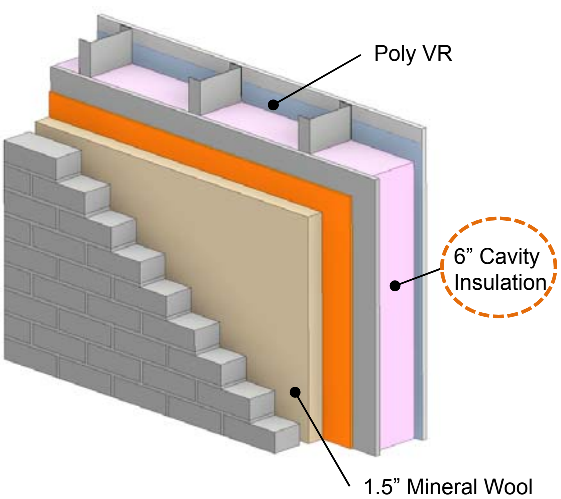
Minneapolis, Minnesota

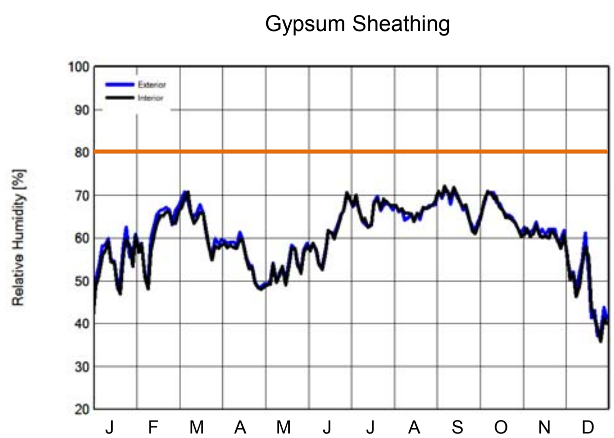
47

Design Considerations: Moisture Control

R 26.5

Cavity Depth





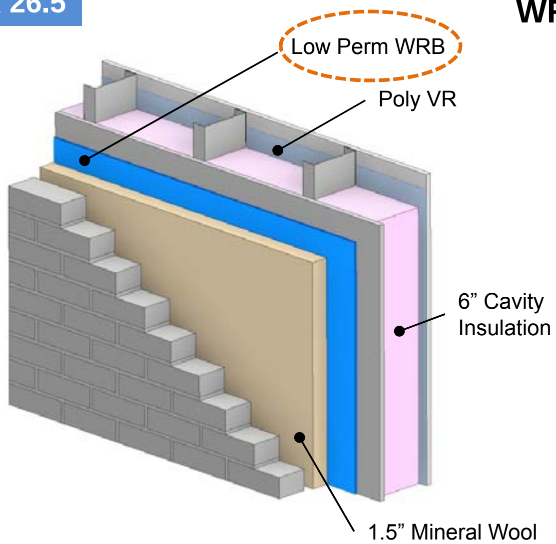
Minneapolis, Minnesota

48

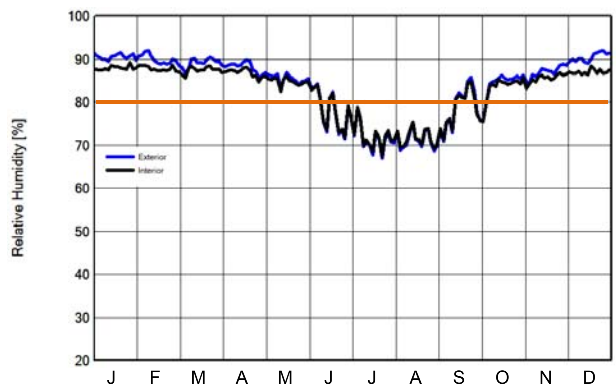
Design Considerations: Moisture Control

R 26.5

WRB Perm



Gypsum Sheathing



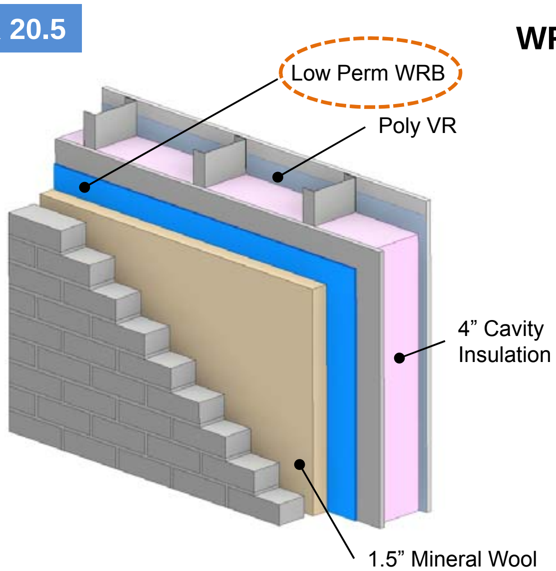
Minneapolis, Minnesota

49

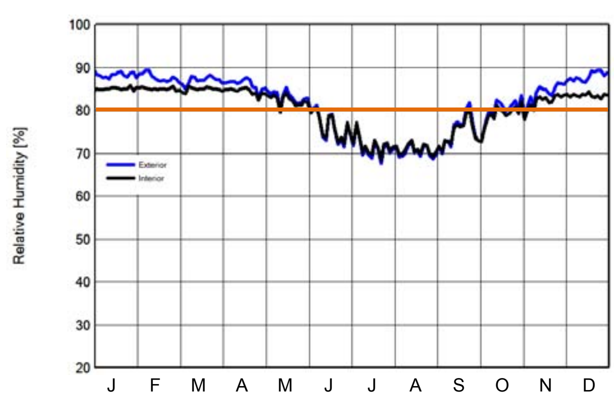
Design Considerations: Moisture Control

R 20.5

WRB Perm: MW



Gypsum Sheathing



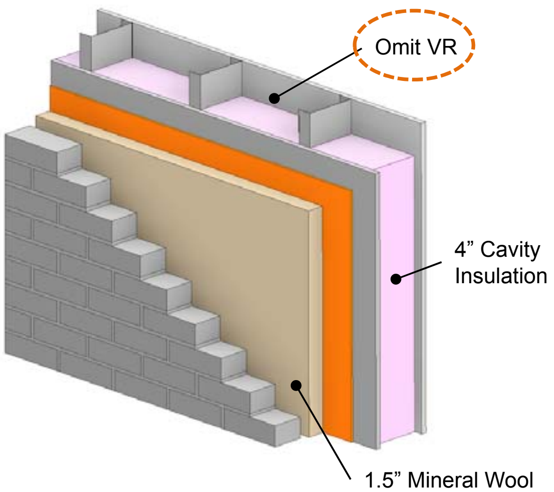
Minneapolis, Minnesota

50

Design Considerations: Moisture Control

R 20.5

Omit VR



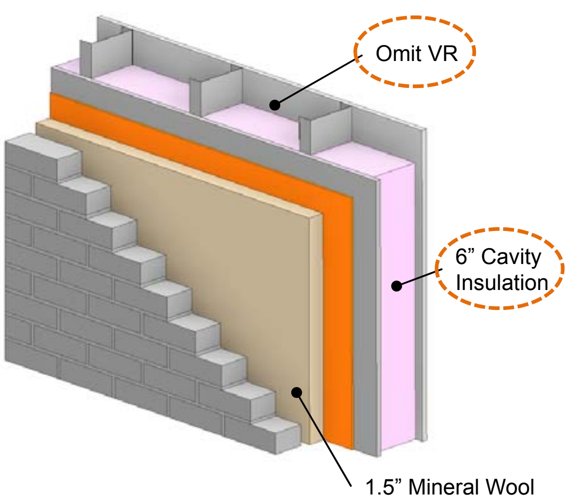
Minneapolis, Minnesota

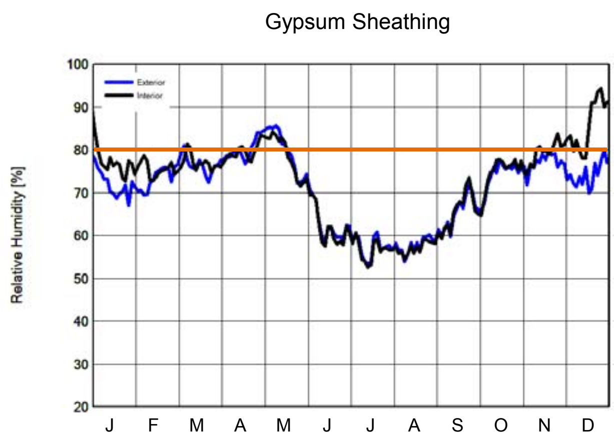
51

Design Considerations: Moisture Control

R 26.5

Omit VR + 6" Cavity



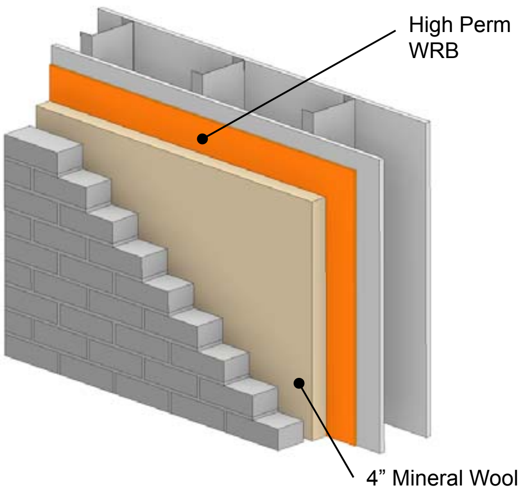


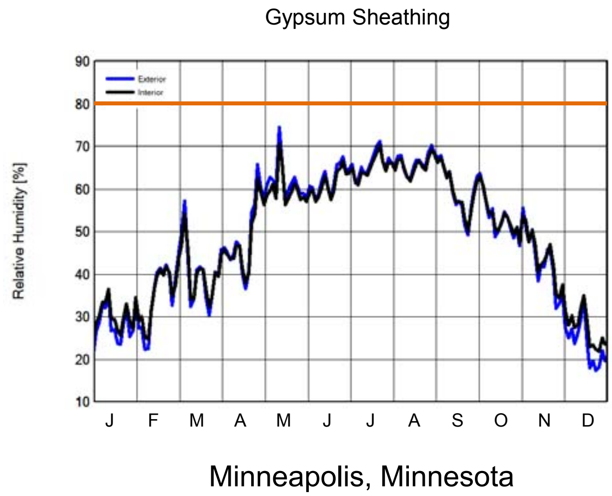
Minneapolis, Minnesota

52

Design Considerations: Moisture Control

U 0.052



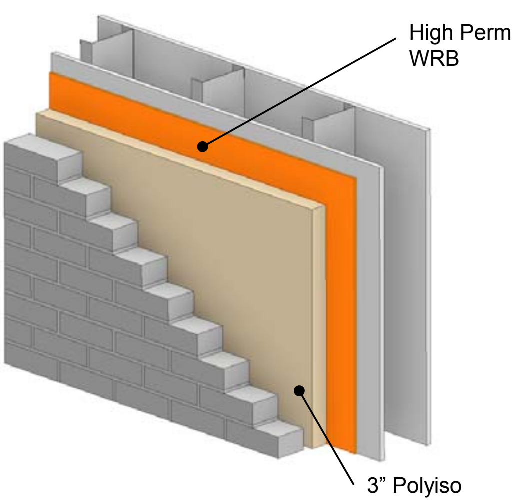


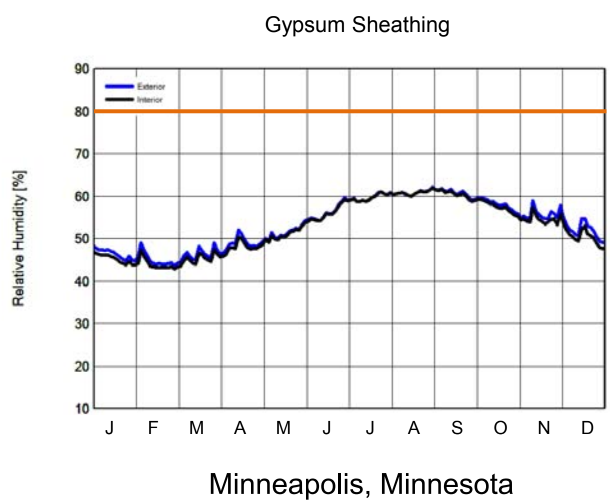
53

Design Considerations: Moisture Control

U 0.052

Omit Cavity Insulation



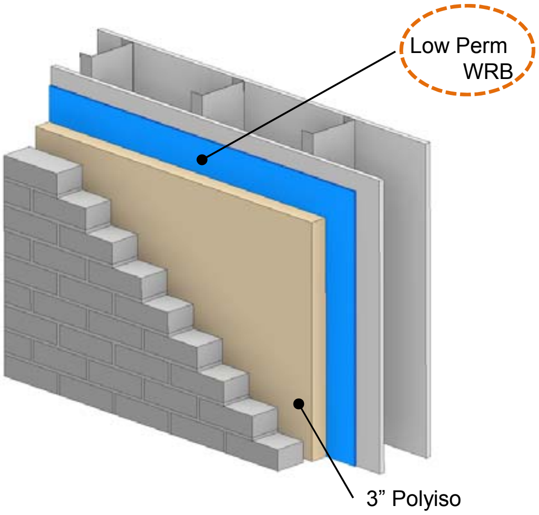


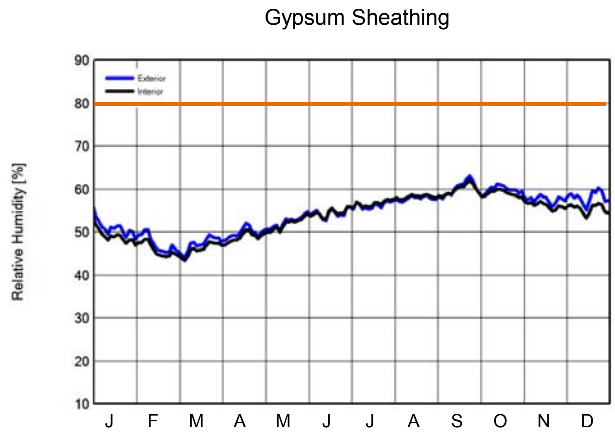
54

Design Considerations: Moisture Control

U 0.052

Omit Cavity Insulation





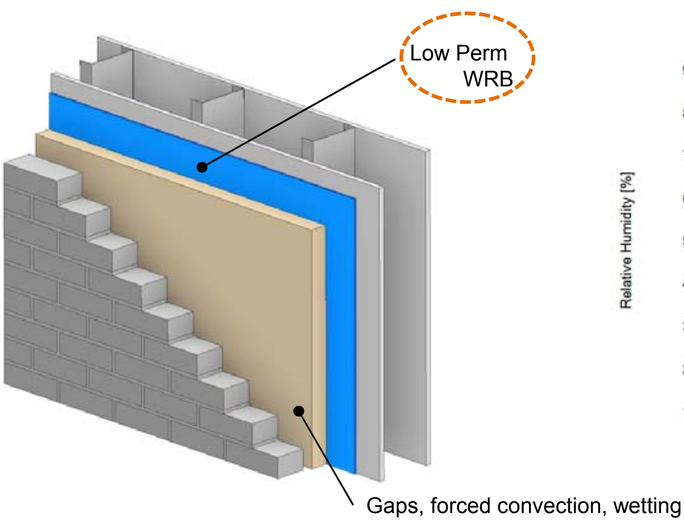
Minneapolis, Minnesota

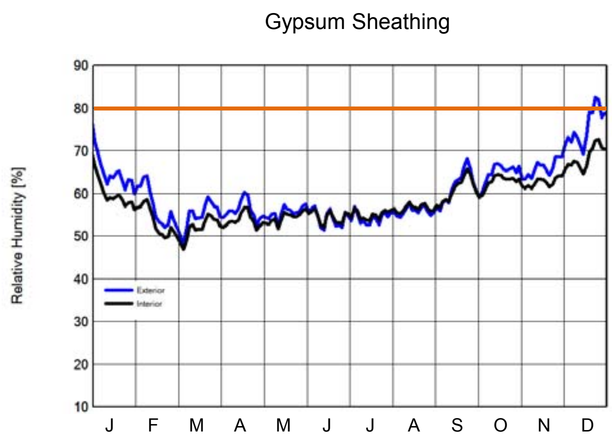
55

Design Considerations: Moisture Control

U 0.09

Reduced Effective R value





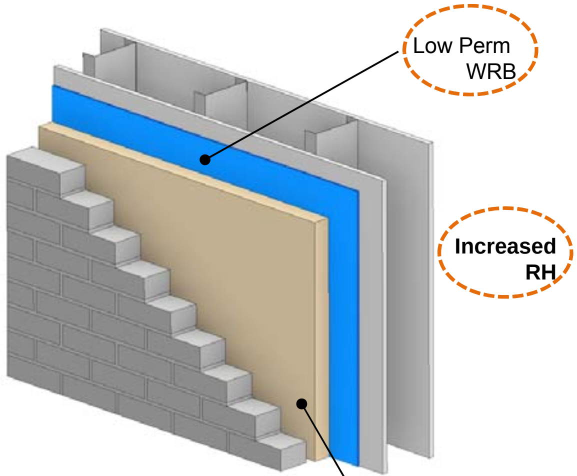
Minneapolis, Minnesota

56

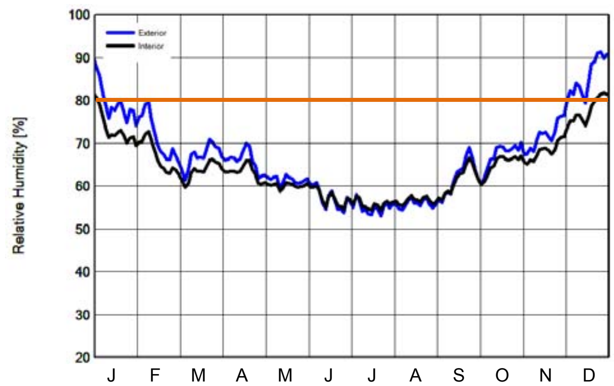
Design Considerations: Moisture Control

U 0.09

Reduced Effective R value



Gypsum Sheathing



Minneapolis, Minnesota

Design Considerations: Moisture Control

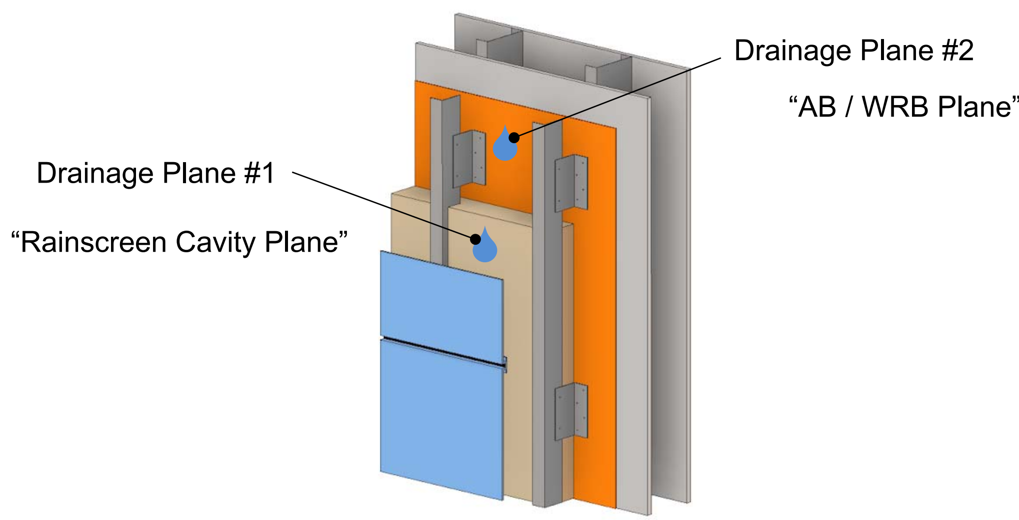
Summary: Several factors affect wall performance

- Proportion of exterior and interior insulation
- Configured Air / WRBs
- Continuity of Exterior Insulation
  - Gaps and wind washing
- Continuity of Interior Vapor Retarder
- Air leakage & exfiltration
- Assumptions regarding moisture loading (wind-driven rain)
  - How much? Distribution?
  - Hygrothermal Model Assumptions
- Climate
  - Exterior climate extremes, Interior RH

Design Considerations

The Drainage Plane

Design Considerations: Drainage Plane



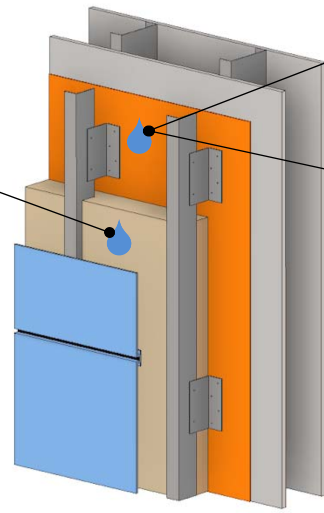
Design Considerations: Drainage Plane

Drainage Plane #2

"AB / WRB Plane"

Drainage Plane #1

"Rainscreen Cavity Plane"



1%

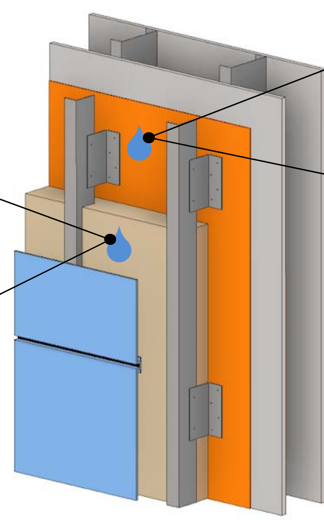
Design Considerations: Drainage Plane

Drainage Plane #2

"AB / WRB Plane"

Drainage Plane #1

"Rainscreen Cavity Plane"



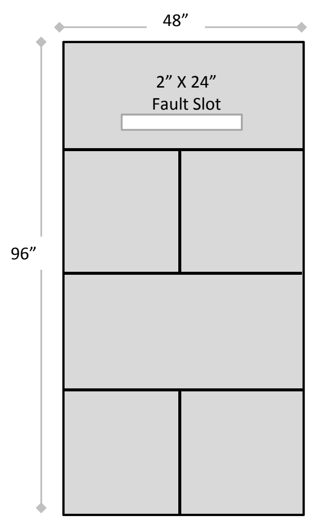
Problems
Not at AB / WRB plane,

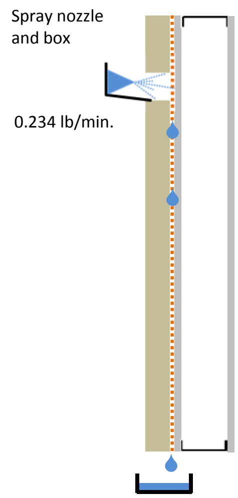
Not continuous with typical wall flashings

Problems
Primary plane has low drainage efficiency due to limited gapping between interfacing materials

Increasing the gap creates air bypasses

Design Considerations: Drainage Plane





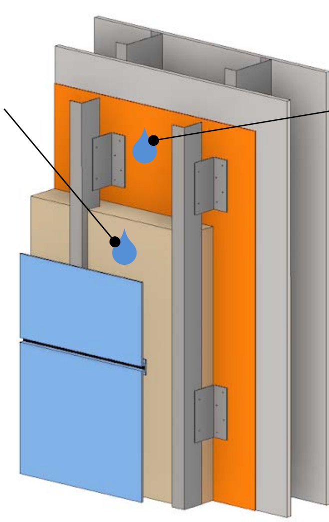
ASTM E2273. Standard Method for Determining the Drainage Efficiency of Exterior Insulation and Finish Systems (EIFS) Clad Wall Assemblies

- *75 minute spraying*
- *Measured at 15-inte intervals*
- *Collected 60 minutes after spraying terminated*
- *Flow collection / total applied*
- *Criteria: 90% efficiency*

Design Considerations: Drainage Plane

Rainscreen Cavity Plane: active drainage plane

- Kinetic Energy
- Drainage Space
- Gravity
- Surface Tension
- Capillary Action
- Pressure Differentials
- Microfluidics



AB / WRB Plane: water films / low drainage

- Depth of voids vary but are insufficient for drainage
- What is the drying potential?
- What is the effect on thermal conductivity?
- Absorptivity of AB / WRB?
- Requires better understanding of water resistance of WRB.

Design Considerations: Drainage Plane

Water-Resistive Barrier - A material behind an exterior wall covering that is intended to resist liquid water that has penetrated behind the exterior covering from further intruding into the exterior wall assembly.

Design Considerations: Drainage Plane

ASTM INTERNATIONAL
Standards Worldwide

ASTM E2556 - *Standard Specification for Vapor Permeable Flexible Sheet Water-Resistive Barriers Intended for Mechanical Attachment.*

Water Resistive Barrier - a material that is intended to resist liquid water that has penetrated the cladding system.

Design Considerations: Drainage Plane

Water vapor permeance is not the primary function of WRBs.
The primary function is resistance to liquid water.



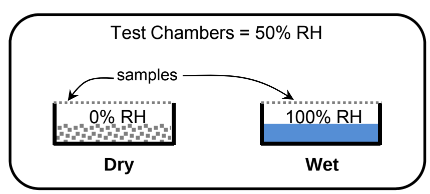

Design Considerations: Drainage Plane

Water Resistance (liquid water)

- "boat method" (ASTM D779),
- "water ponding" method (CCMC 07102 section 6.4.5)
- "hydrostatic head method" (AATCC 127)
  - ASTM E2556 – Standard Specification for Vapor Permeable Flexible Sheet Water-Resistive Barriers Intended for Mechanical Attachment

Water Vapor Transmission

- Desiccant Method – "dry cup" (ASTM E96)
- Water Method – "wet cup" (ASTM E96)
- ASTM D1653 (organic coating films)
- ASTM E398



ASTM E96

Design Considerations: Drainage Plane

E2556/E2556M – 10

TABLE 1 Requirements for Water Resistive Barriers

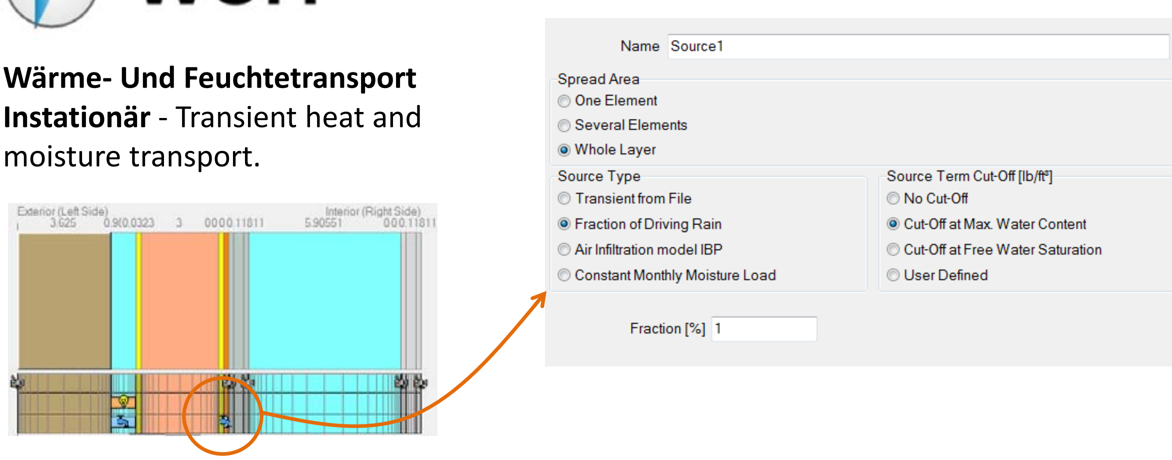
Test Requirement	Specimen Type	Test Method	Minimum Performance Requirements Type I	Minimum Performance Requirements Type II
Dry tensile strength or dry breaking force (choose 1)	(1) as manufactured and (2) aged in accordance with A1.2	Test Method D828 for paper and felt materials, or Test Methods D882 for polymeric materials, or Test Method D5034 (Grab Method)	3500 N/m (20 lb/in.) minimum (machine and cross direction) 3500 N/m (20 lb/in.) minimum (machine and cross direction) 178 N (40 lbf) minimum (machine direction) 156 N (35 lbf) minimum (cross direction)	
Water resistance test (choose 1)	(1) as manufactured and (2) aged in accordance with A1.2	Test Method D779, or Water Resistance Ponding Test (A1.1), or AATCC Test Method 127 except that the specimens shall be held at a hydrostatic head of 55 cm (21.6 in.)	10 min minimum No water shall penetrate through the membrane in 120 min not applicable	60 min minimum not applicable No leakage is permitted to the underside of any specimen in 5 h
Water vapor transmission test	as received	Test Method E96/E96M (Dessicant Method)	290 ng/(Pa · s · m^2) (5 perms) minimum	
Pliability test	as received	see A1.3	The material shall not crack when bent over a 1.6 mm (1⁄16-in.) diameter mandrel at a temperature of 0°C (32°F)	

Design Considerations: Drainage Plane

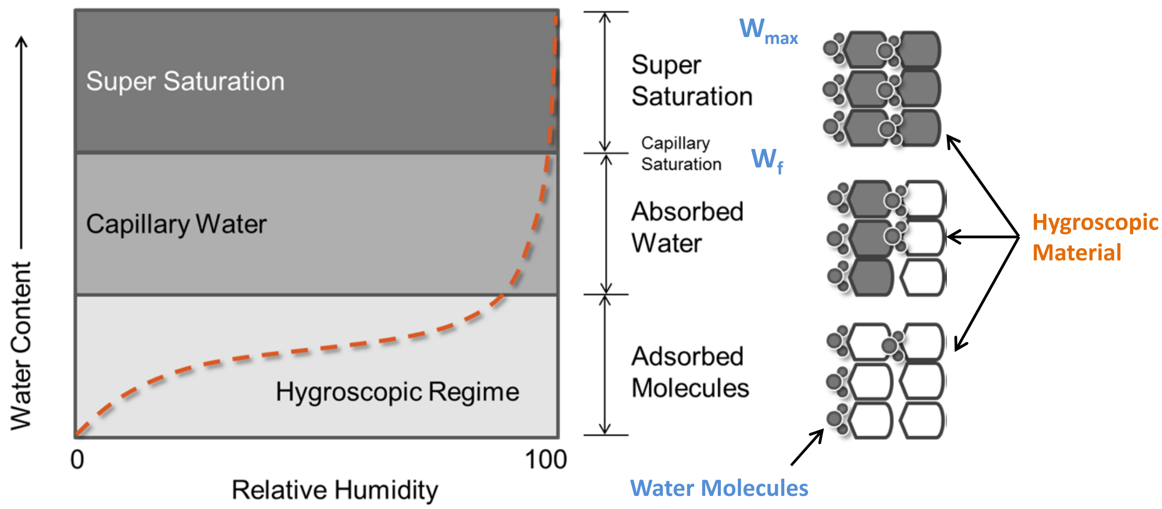
WUFI®

‘Moisture Clipping’

Wärme- Und Feuchtetransport Instationär - Transient heat and moisture transport.



Design Considerations: Drainage Plane



Design Considerations: Drainage Plane

WUFI®

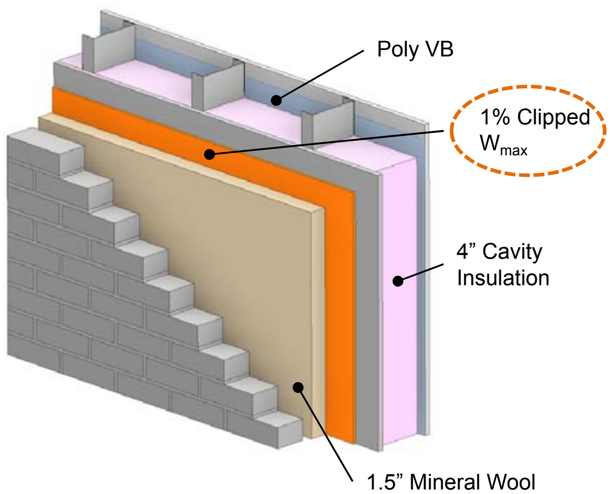
Material Properties

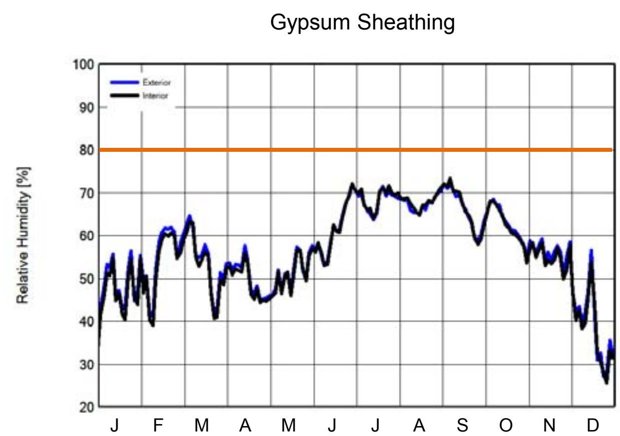
Basic Data - required
- bulk density
- porosity
- specific heat capacity of dry material
- thermal conductivity of dry material
- water vapor diffusion resistance factor of dry material

Hygric Extensions - refinement
- moisture storage function
- liquid transport coefficient for suction
- liquid transport coefficient for redistribution
- moisture-dependent thermal conductivity
- moisture-dependent vapor diffusion resistance factor

Design Considerations: Moisture Control

R 20.5



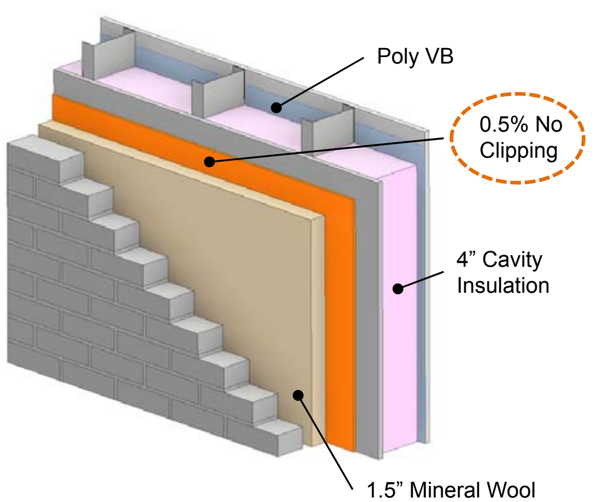


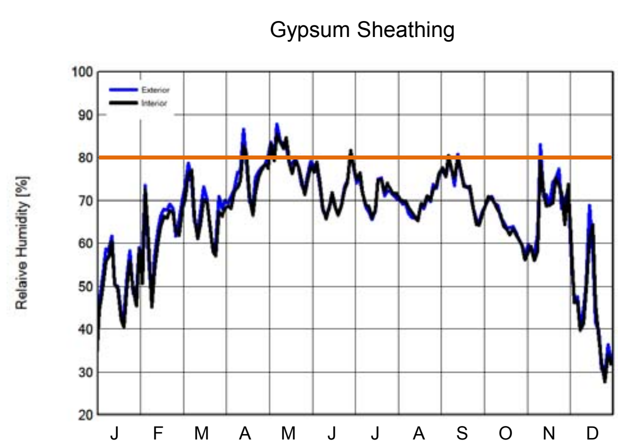
Minneapolis, Minnesota

73

Design Considerations: Moisture Control

R 20.5



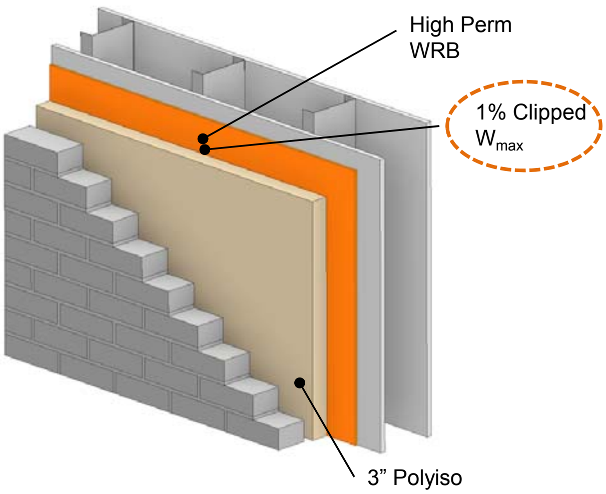


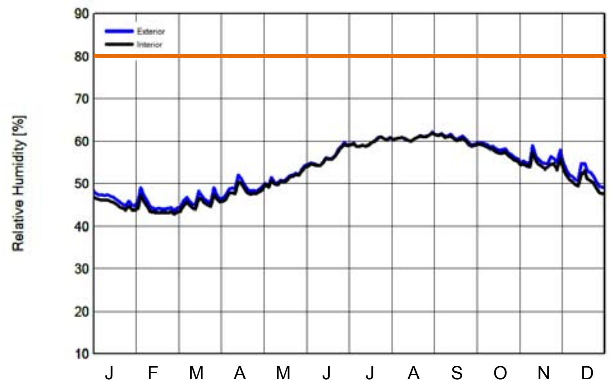
Minneapolis, Minnesota

74

Design Considerations: Moisture Control

U 0.052



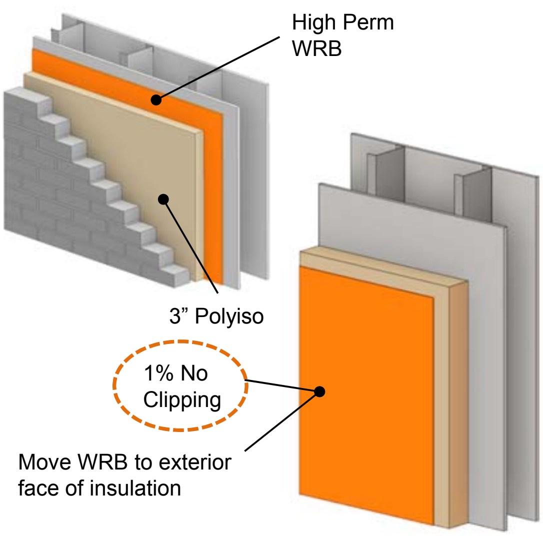


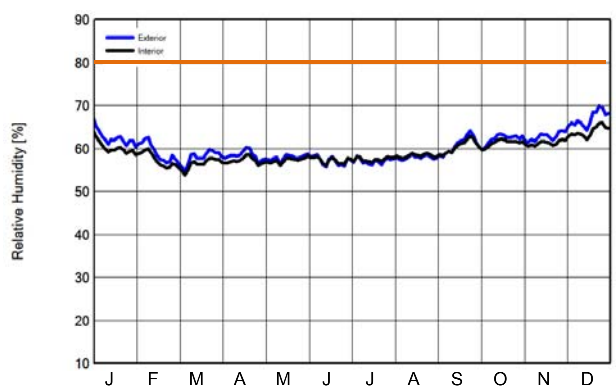
Minneapolis, Minnesota

75

Design Considerations: Moisture Control

U 0.052





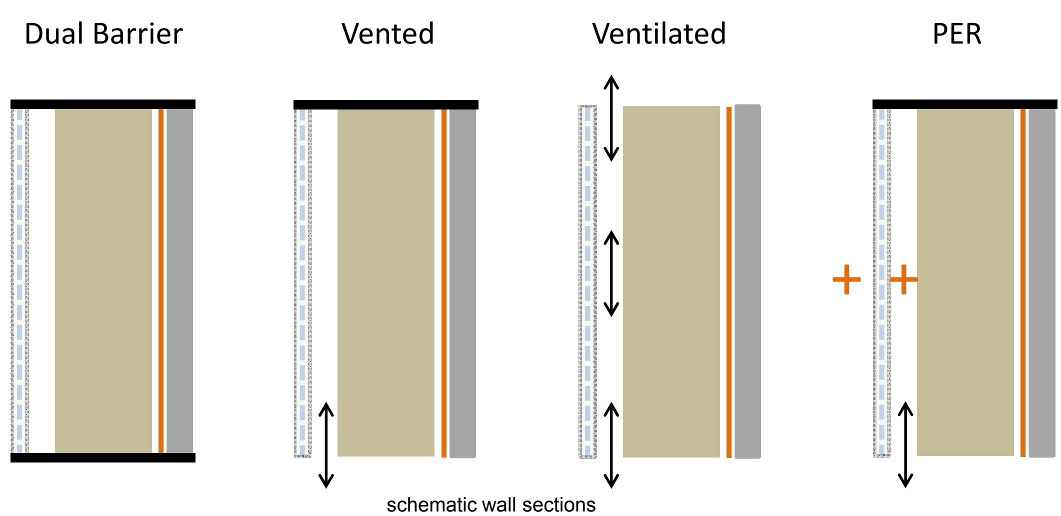
Minneapolis, Minnesota

76

Design Considerations

Rainscreens

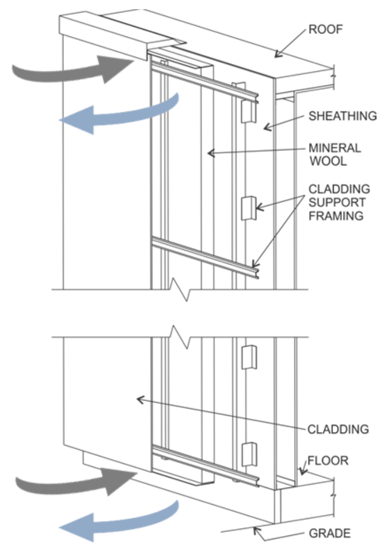
Design Considerations: Rainscreens



Design Considerations: Rainscreens

Critical Questions

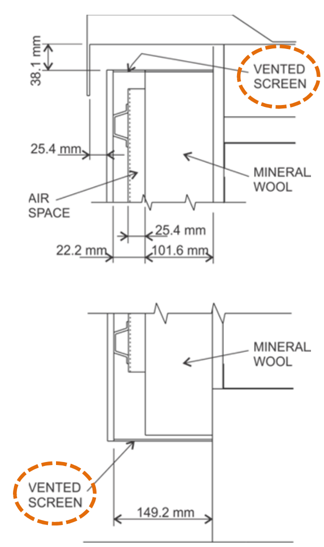
1. Do I need a rainscreen?
2. What is the preferred strategy?
   - Cladding system, assembly materials
3. What are the system's flow velocities?
4. What are the system's ACH?
5. Is the CI compromised by airflow?
   - Gaps: end gaps & interstitial gaps
   - Vent openings & drainage



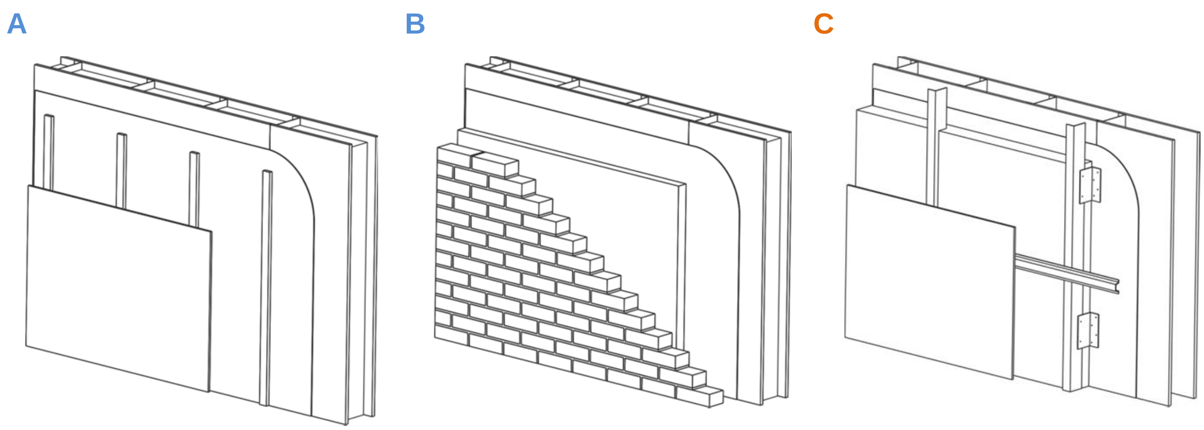
Design Considerations: Rainscreens

Critical Questions

1. Do I need a rainscreen?
2. What general strategy is necessary?
   - Cladding system, assembly materials
3. What are the system's flow velocities?
4. What are the system's ACH?
5. Is the CI compromised by airflow?
   - Gaps: end gaps & interstitial gaps
   - Vent openings & drainage



Design Considerations: Rainscreens



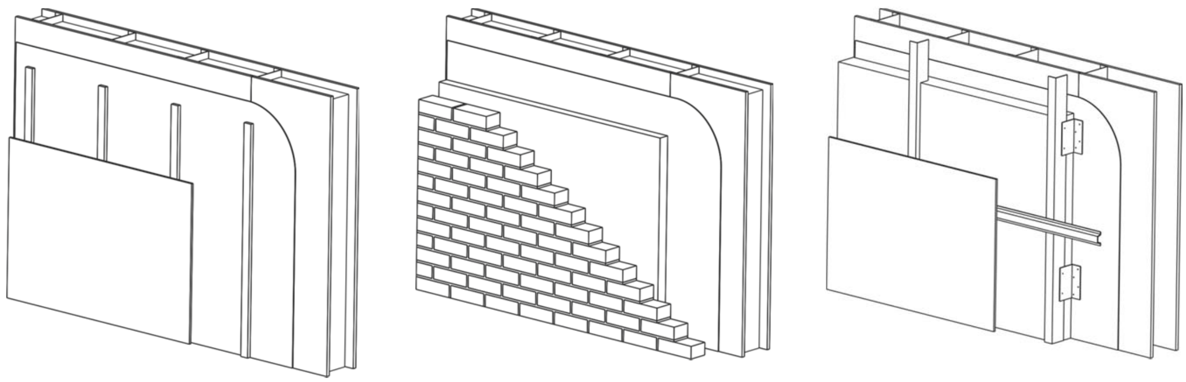
Simpler, Planar Airflow Paths

Complex Airflow Paths

Session Break

Case Study: Rainscreen Airflows

A B C



Simpler, Planar Airflow Paths

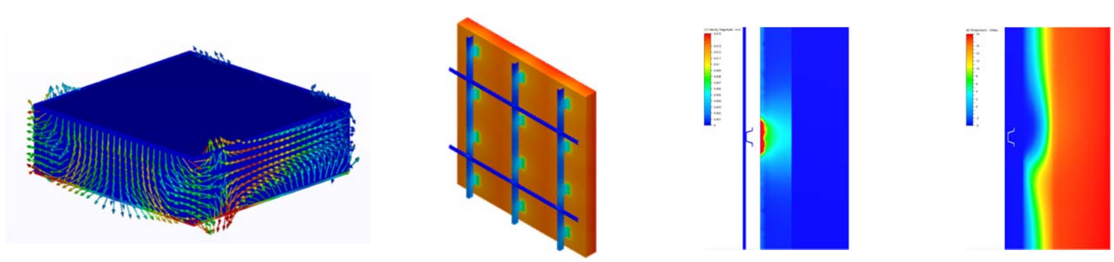
Complex Airflow Paths

Case Study: Rainscreen Airflows

Study Approach

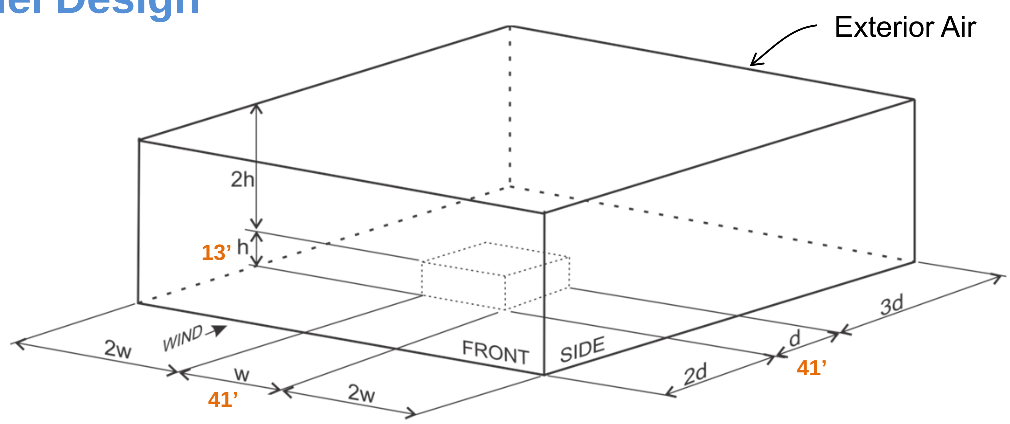
Computation Fluid Dynamics – Mathematical models used to simulate fluid/gas flow and heat transfer.

- Allows 'numeric experimentation' to provide insight into flow patterns that are difficult, expensive or impossible to study using traditional techniques
- Simulation software used: Autodesk CFD 2016



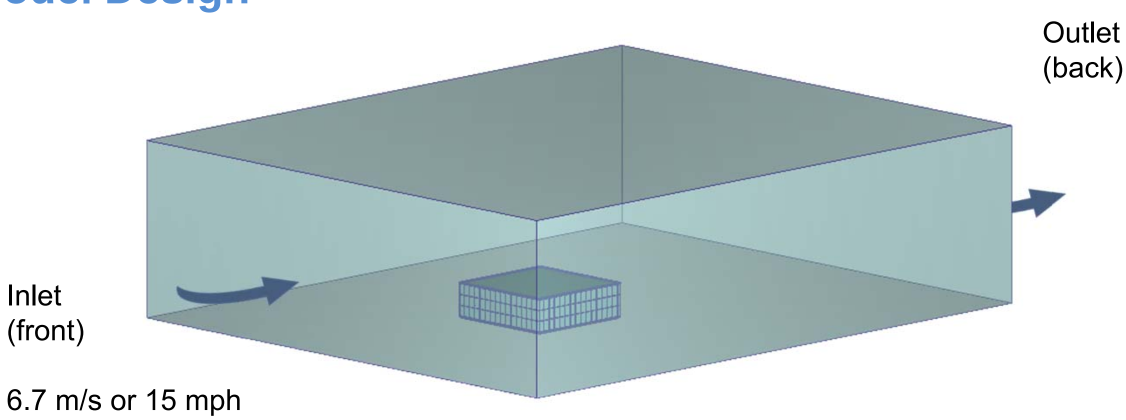
Case Study: Rainscreen Airflows

Model Design



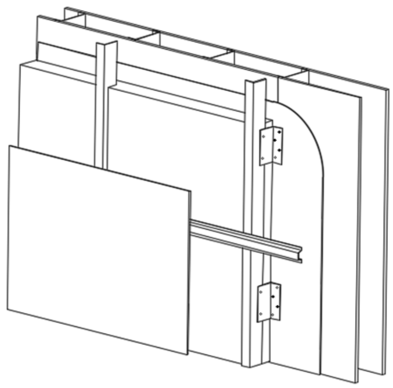
Case Study: Rainscreen Airflows

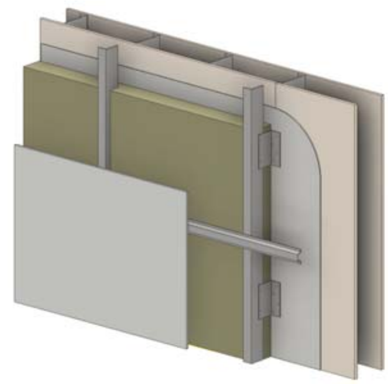
Model Design



Case Study: Rainscreen Airflows

Model Design

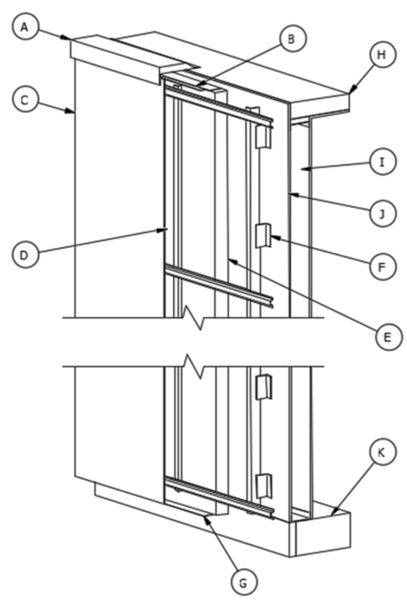




Case Study: Rainscreen Airflows

Model Design

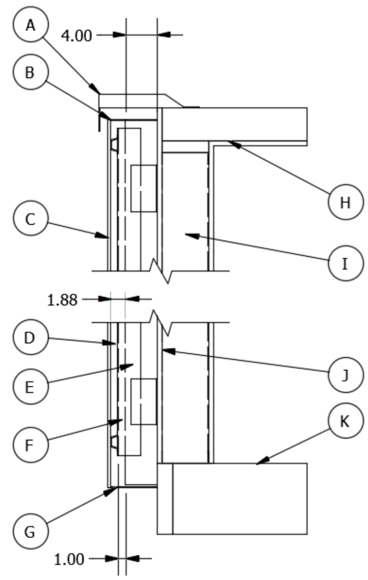
A Coping
B Air screen (top)
C Cladding (HD Fiber Cement)
D Rainscreen air space (1-7/8”)
E Mineral wool (4”)
F Cladding support system
G Air screen (bottom)
H Roof insulation (XPS)
I Interior gypsum (5/8”)
J Gypsum sheathing (5/8”)
K Concrete floor slab



Case Study: Rainscreen Airflows

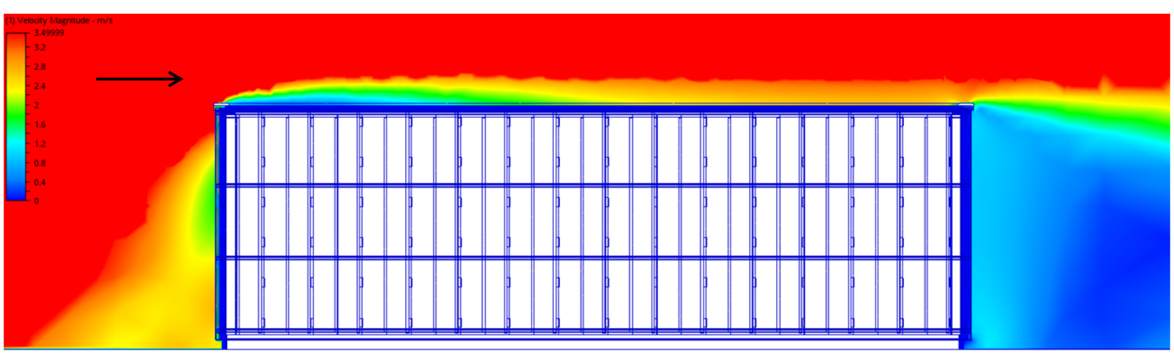
Model Design

A Coping
B Air screen (top)
C Cladding (HD Fiber Cement)
D Rainscreen air space (1-7/8”)
E Mineral wool (4”)
F Cladding support system
G Air screen (bottom)
H Roof insulation (XPS)
I Interior gypsum (5/8”)
J Gypsum sheathing (5/8”)
K Concrete floor slab



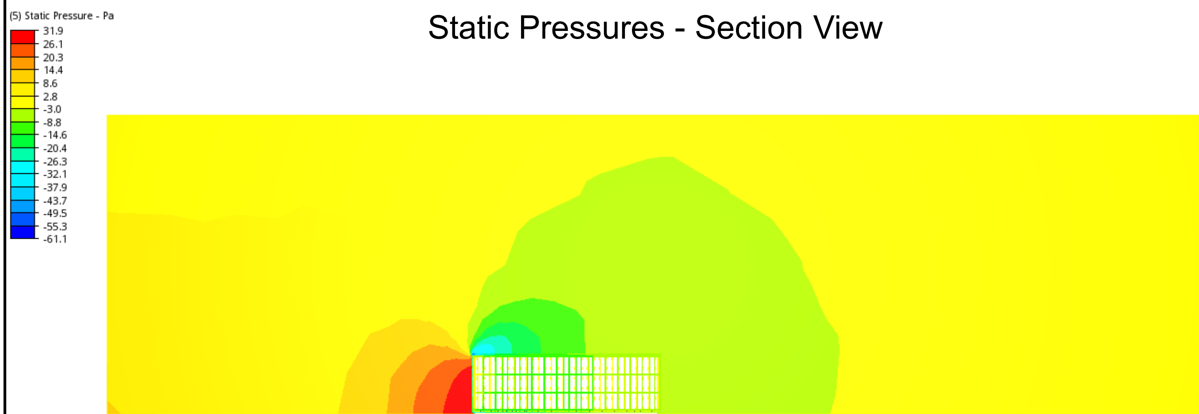
Case Study: Rainscreen Airflows

Air Velocities - Section View



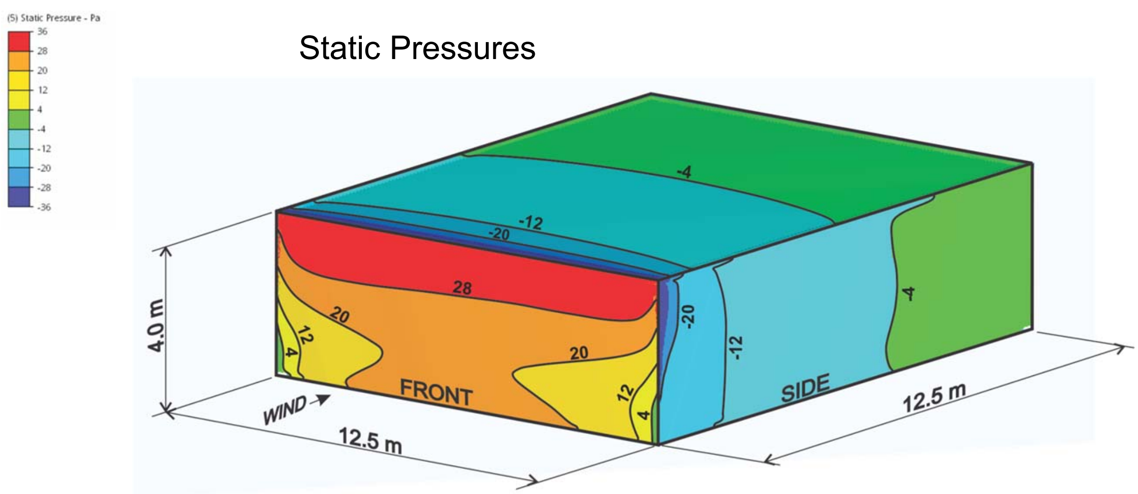
Case Study: Rainscreen Airflows

Static Pressures - Section View



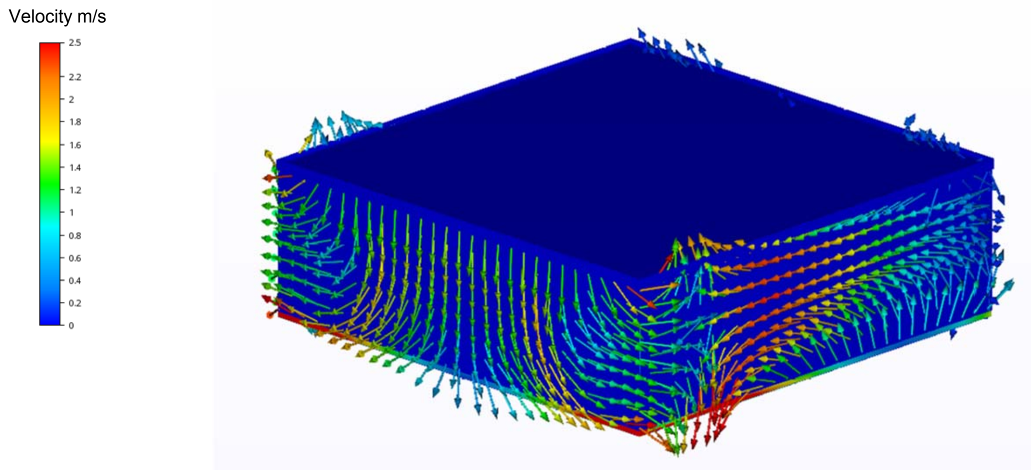
Case Study: Rainscreen Airflows

Static Pressures



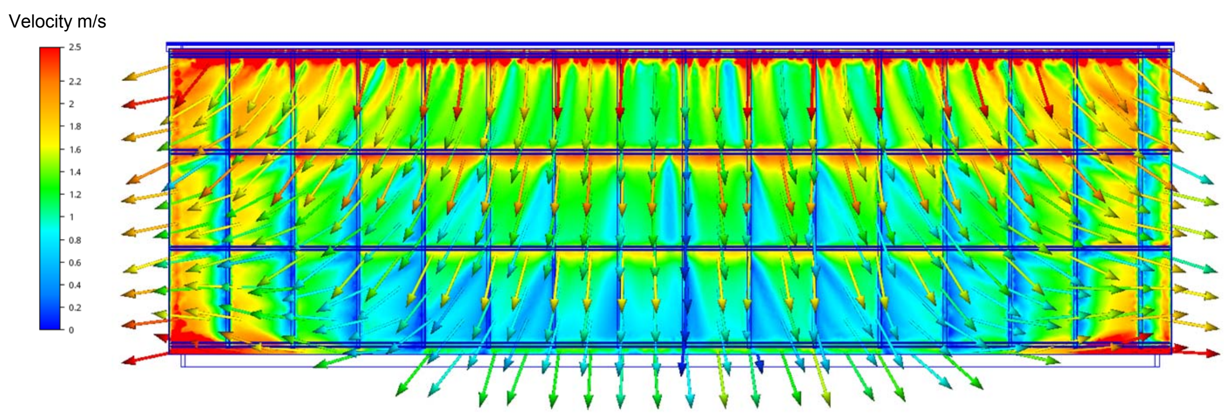
Case Study: Rainscreen Airflows

Air Velocities within the Rainscreen Cavity



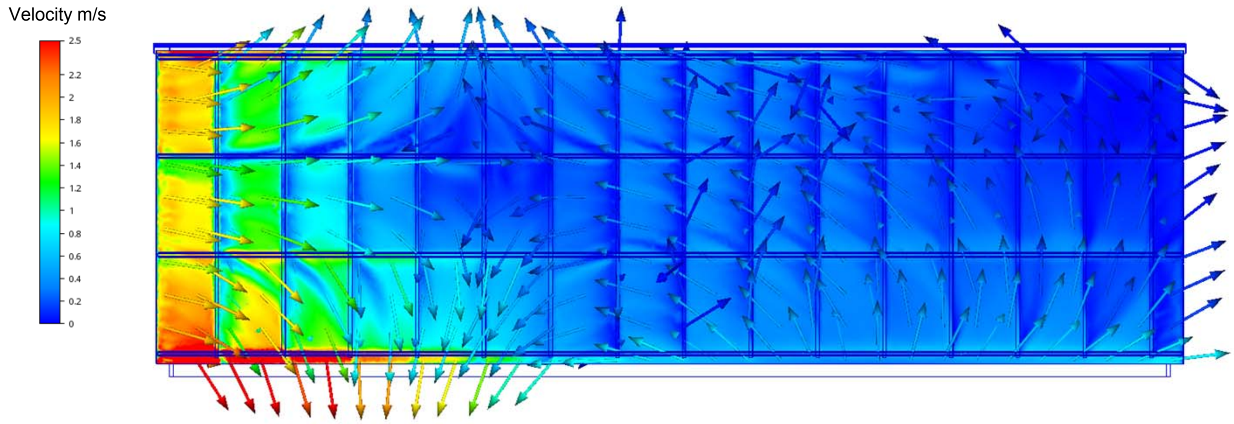
Case Study: Rainscreen Airflows

Windward Wall



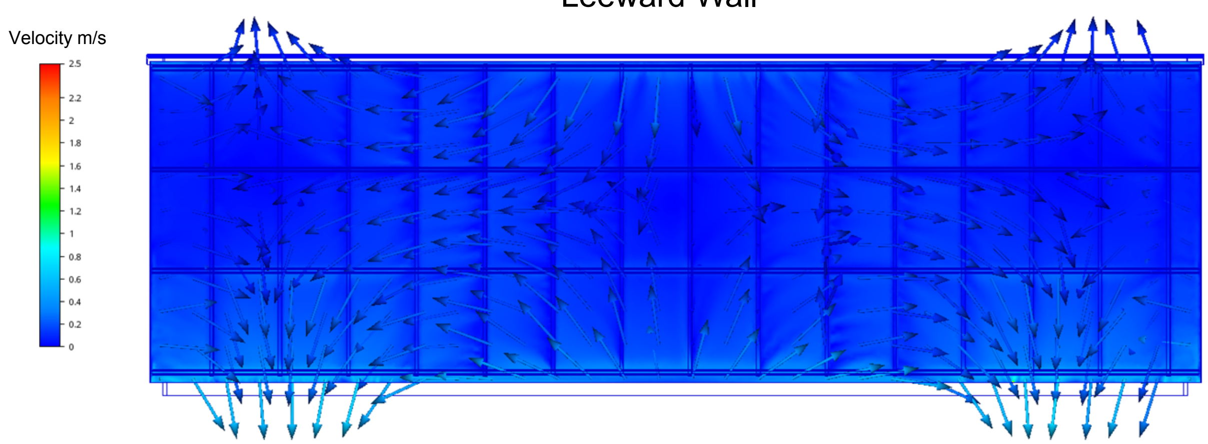
Case Study: Rainscreen Airflows

Side Wall



Case Study: Rainscreen Airflows

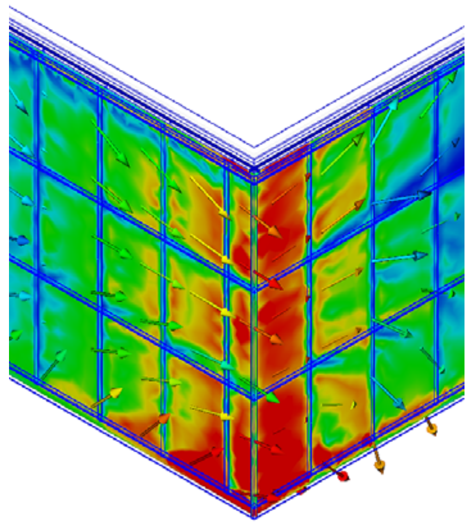
Leeward Wall



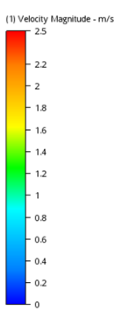
Case Study: Rainscreen Airflows

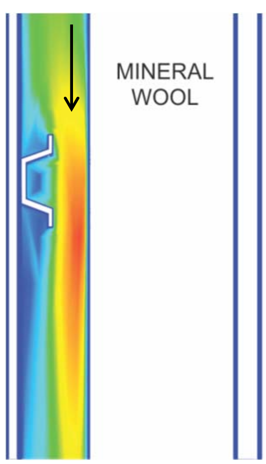
Corner Domains:

- Increased air velocities
- Increased mixing & turbulence
- Not localized to a small area – up to 1/3 of each elevation classified as 'corner domain'

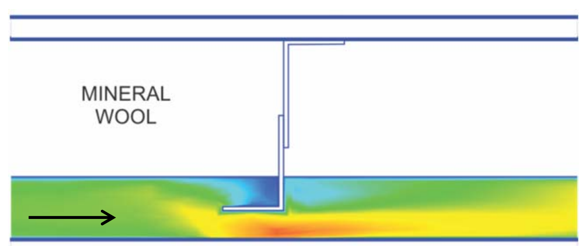


Case Study: Rainscreen Airflows





Section View

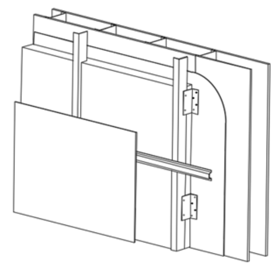


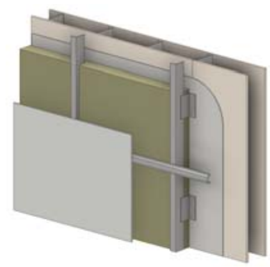
Plan View

Case Study: Rainscreen Airflows

Study Findings

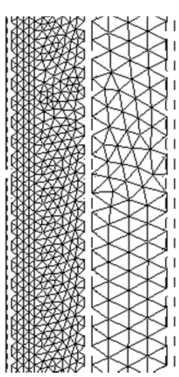
- Dynamic pressures were consistent with known principles for wind loading.
- Air velocities with the rainscreen cavity ranged from 0.1 to 3 m/s.
- Highest velocities occurred in association with inlets, windward corners, and at hat channels and vertical girts.
- Velocities were similar to those found in open rainscreens; however flow patterns were more consistent with conventional back-ventilated systems.



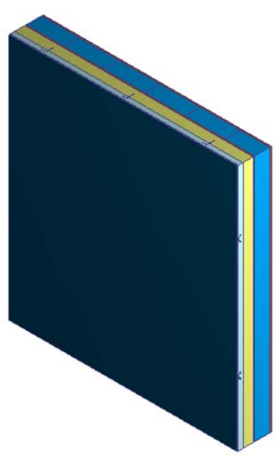


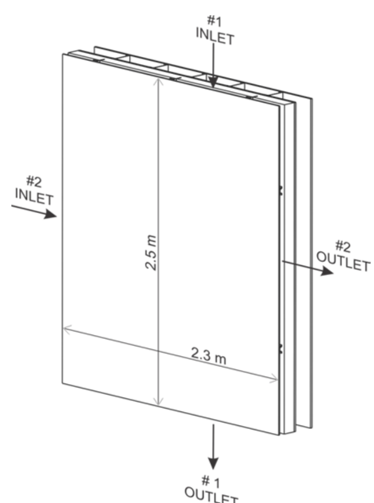
Case Study: Convective Heat Loss

Decoupled Model

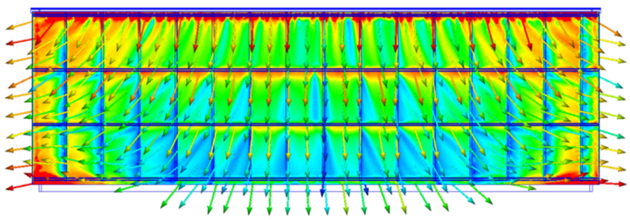


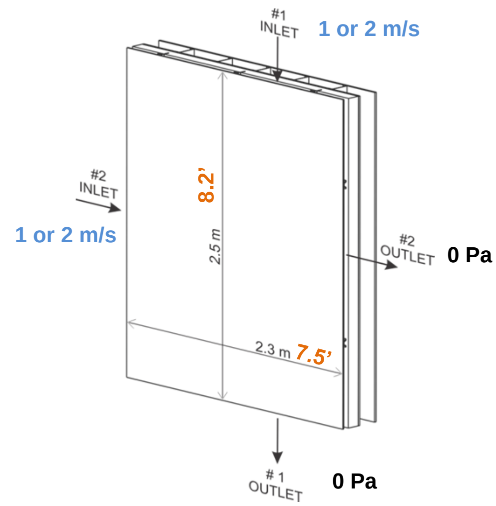
Meshing





Case Study: Convective Heat Loss



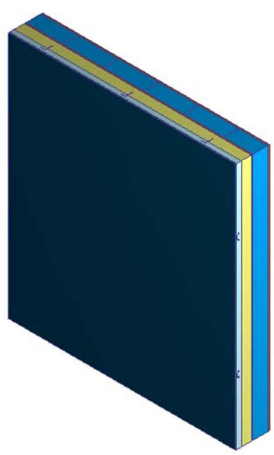


Known air velocities from wind study were used to create simplified vertical and horizontal airflows

Case Study: Convective Heat Loss

Winter design conditions reflective of most of North America

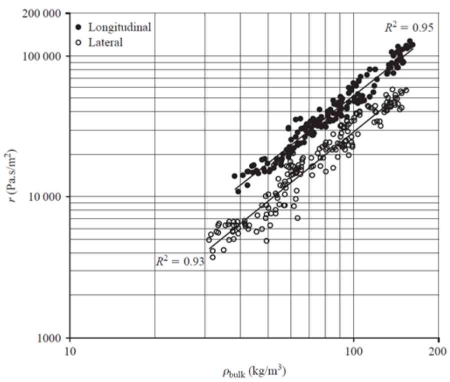
Exterior Temperature
-5°C (23°F)



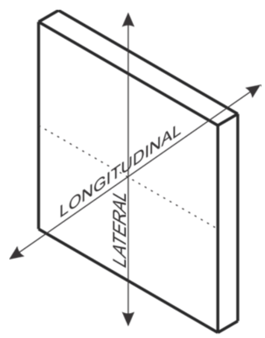
Interior Temperature
21°C (69.8°F)

Case Study: Convective Heat Loss

Considerations: Air Permeability of Mineral Wool



Hopkins C. 2007. Sound Insulation.
Published by Elsevier Ltd. ISBN: 978-0-7506-6526-1. 648 p:79-82.



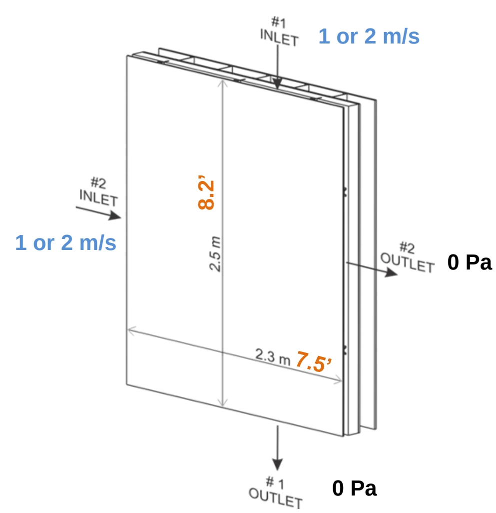
Influenced by . . .

- Density
- Matrix composition
- Fiber size
- Fiber orientation
  - Lateral perm: 50% higher
- Fiber inhomogeneity
- Pressure
  - ISO 9053 / EN 29063
  - 0.2 Pa
  - 30% higher at 5 – 10 Pa

Case Study: Convective Heat Loss

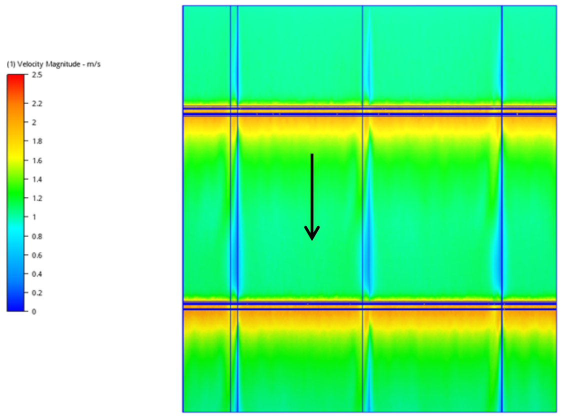
Study Design

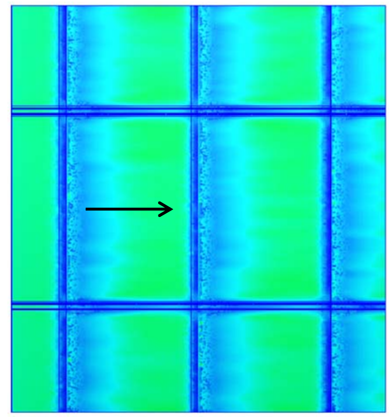
Permeability (m^2)	Permeability (m^3/Pa·m·s)	Resistivity (Pa·s/m^2)	Density (kg/m^3)
2.0 x 10^{-10}	11.1 x 10^{-6}	90,000	160
4.0 x 10^{-10}	22.2 x 10^{-6}	45,000	90
6.0 x 10^{-10}	33.3 x 10^{-6}	30,000	80
8.0 x 10^{-10}	44.4 x 10^{-6}	22,500	70
1.0 x 10^{-9}	55.5 x 10^{-6}	18,000	50
1.5 x 10^{-9}	83.3 x 10^{-6}	12,000	40
2.0 x 10^{-9}	111 x 10^{-6}	9,000	30



Case Study: Convective Heat Loss

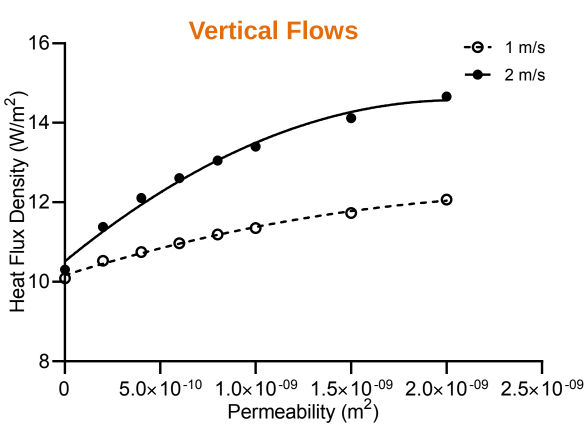
Simplified inlets resulted in simple flow regimes

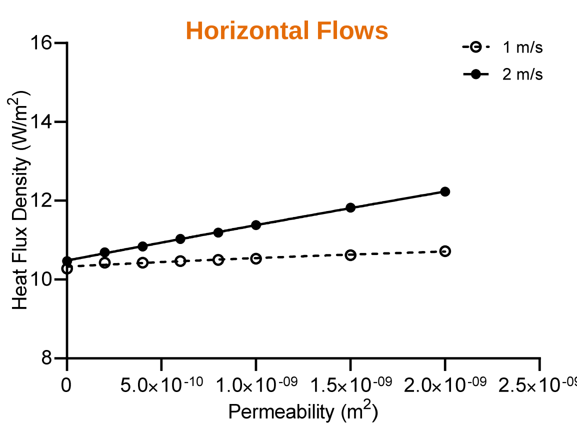




Case Study: Convective Heat Loss

Heat Flux Densities in Response to Vertical & Horizontal Flows





Case Study: Convective Heat Loss

Heat Flux Densities

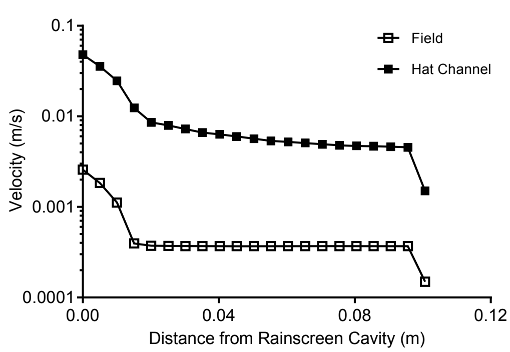
- Vertical flows at 1 m/s: 4 – 20% increase
- Vertical flows at 2 m/s: 10 – 42% increase
- Horizontal flows at 1 m/s: 1.5 – 17% increase
- Horizontal flows at 2 m/s: 2 – 17% increase

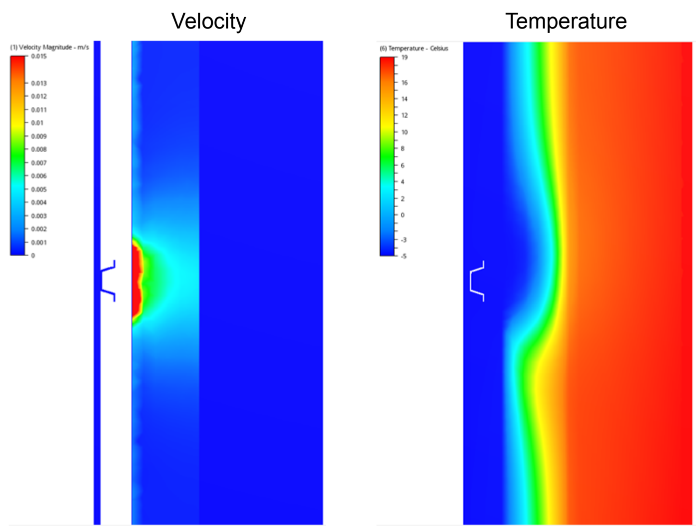
Effective R-values of heat transfer walls as reported in imperial units and as RSI (SI)

Permeability (m^2)	Vertical Flow 1 m/s	Vertical Flow 2 m/s	Horizontal Flow 1 m/s	Horizontal Flow 2 m/s
0 (solid)	14.6 (2.57)	14.3 (2.52)	14.3 (2.52)	14.1 (2.48)
2.0×10^{-10}	14 (2.47)	13.0 (2.29)	14.1 (2.48)	13.8 (2.43)
4.0×10^{-10}	13.7 (2.42)	12.2 (2.15)	14.1 (2.48)	13.6 (2.39)
6.0×10^{-10}	13.4 (2.36)	11.7 (2.06)	14.1 (2.48)	13.4 (2.36)
8.0×10^{-10}	13.2 (2.32)	11.3 (1.99)	14.1 (2.48)	13.2 (2.32)
1.0×10^{-9}	13.0 (2.29)	11.0 (1.94)	14.0 (2.47)	13.0 (2.29)
1.5×10^{-9}	12.6 (2.22)	10.5 (1.85)	13.9 (2.45)	12.5 (2.20)
2.0×10^{-9}	12.2 (2.15)	10.1 (1.78)	13.8 (2.43)	12.1 (2.13)

Case Study: Convective Heat Loss

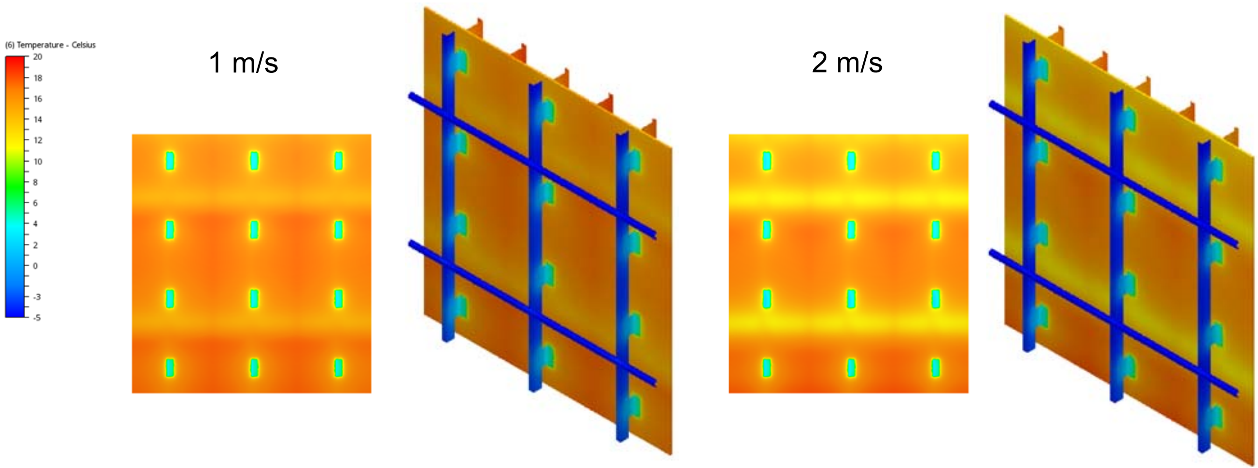
Air Velocities Through Mineral Wool





Case Study: Convective Heat Loss

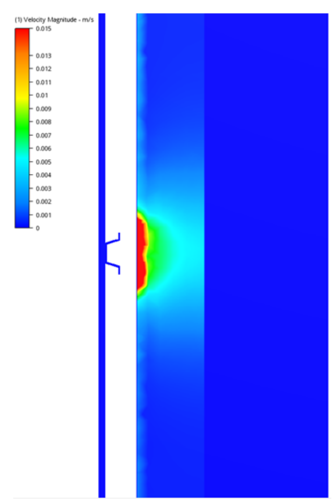
Thermal Conditions at Exterior Surfaces of Wall Sheathing



Case Study: Rainscreen Airflows

Study Findings

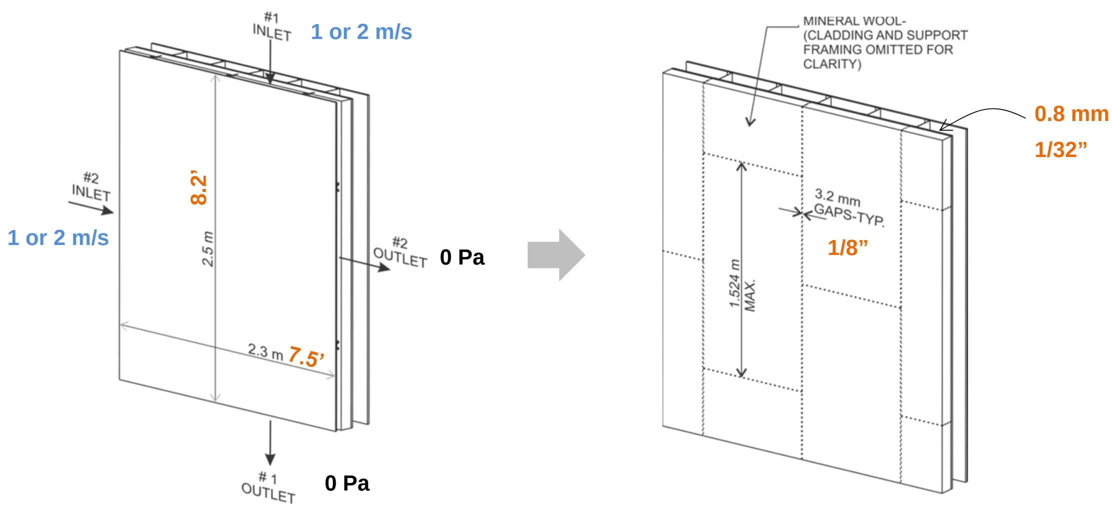
- Forced convection increased heat flux density by 4 to 42%.
- Effective R-values were reduced by approximately 30%.
- Rainscreen geometries play an important role in overall airflow patterns as well as convective heat loss.
- Increased likelihood of moisture accumulation



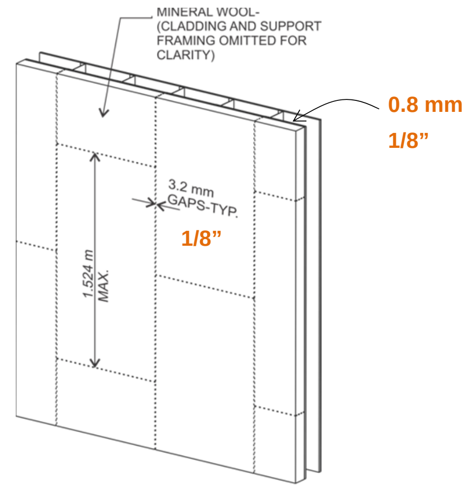
Case Studies

The Effects of Insulation Gaps on Thermal Performance

Case Study: Convective Heat Loss



Case Study: Convective Heat Loss



A single mineral wool permeability was selected for this study: 1.0×10^{-9}. Corresponds to a density of 50 kg/m^3.

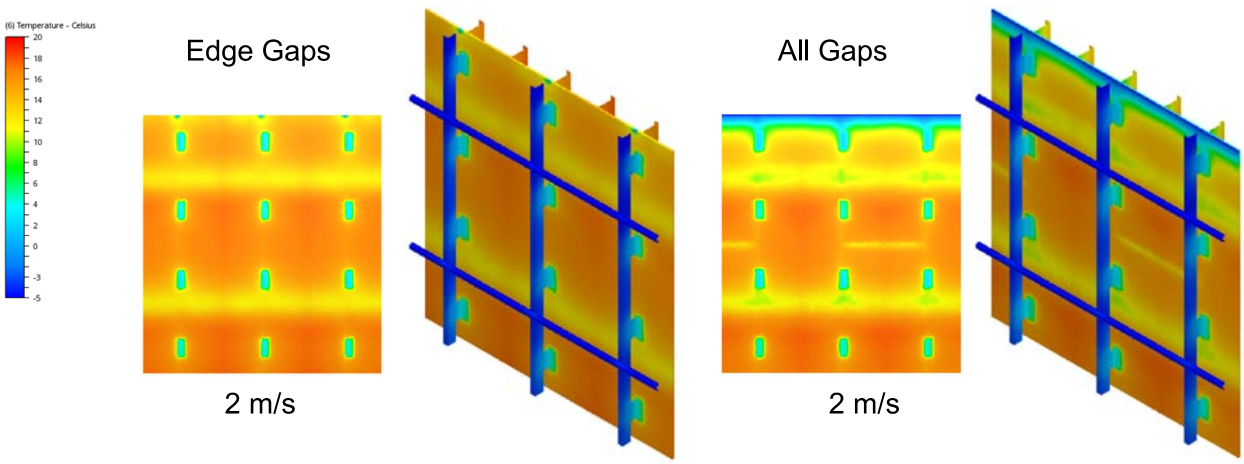
Case Study: Convective Heat Loss

Heat Flux Densities for Edge and Interstitial Gapping

	Heat Flux Density W/m² (Btu/hr/ft²)		
	No Gaps	Edge Gaps 3 to 6%	Interstitial Gap 19 to 25%
1 m/s: vertical airflow	11.4 (3.60)	11.9 (3.78)	13.5 (4.27)
1 m/s: horizontal airflow	10.5 (3.34)	11.1 (3.51)	12.7 (4.04)
2 m/s: vertical airflow	13.4 (4.25)	13.9 (4.40)	16.7 (5.31)
2 m/s: horizontal airflow	11.4 (3.61)	11.8 (3.75)	14.1 (4.48)

Case Study: Convective Heat Loss

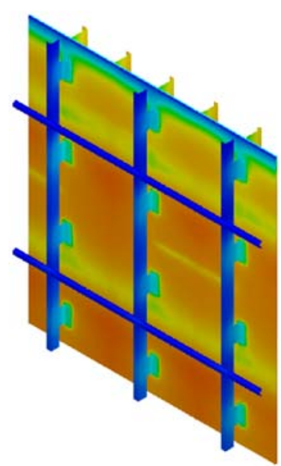
Thermal Conditions at Exterior Surfaces of Wall Sheathing



Case Study: Rainscreen Airflows

Study Findings

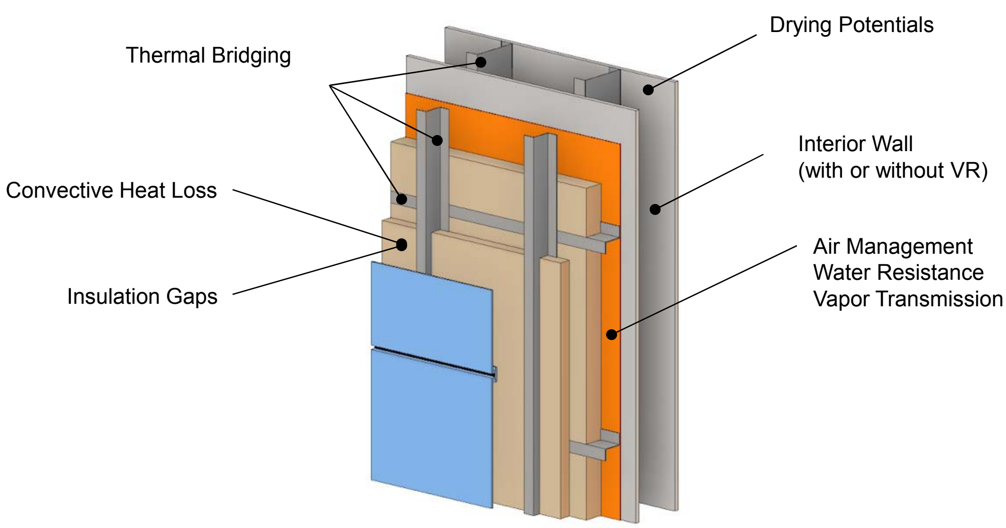
- Edge gapping: 3-6% increase in heat flux density
- Interstitial Gapping + Edge Gapping: 19-25%.
- Heat flux density increased by 62% when compared to non-gapped impermeable condition.
- Impermeable insulation: 89% increase in heat loss due to gapping
- Considerations for wind barriers, sealed joints, adhered slabs. Alternatively, correction factors should be employed.



Design Strategies

Strategies for Higher Performing Walls

Design Strategies



Strategies for Higher Performing Walls

Primary Objective: Combine safe, efficient insulation strategies with high moisture resilience.

Moisture Resilience – The assembly's ability to accommodate moisture loading from exterior and interior sources

Liquid Water Resistance

+

Water Vapor Transmission

→

Improved Moisture Transport
- Effective drying
- Safe moisture storage

Strategies for Higher Performing Walls

The Building Enclosure Core

A design concept that emphasizes moisture resilience in achieving the highest thermal efficiency.

1 Simplicity

2 Adaptability

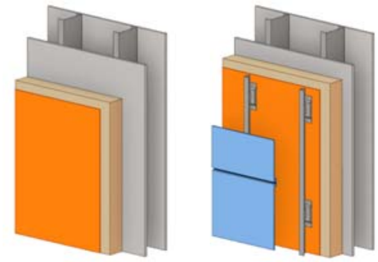
3 Performance

Moisture Resilience
- Accommodates high moisture loading
- High drying capacity
- Redundant safeguards
- Independent of cladding type
- Considers human and climate factors

Thermal Efficiency
- Emphasizes exterior CI
- Minimizes thermal bridging
- Prevents convective heat loss
- High R-values
- Adaptable to all climates

Strategies for Higher Performing Walls

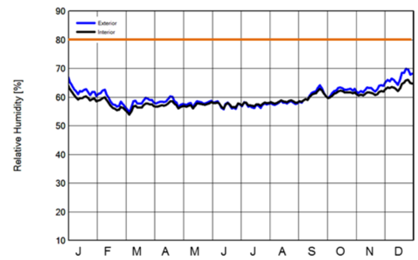
The Building Enclosure Core: An Example



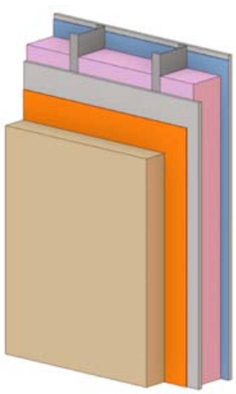
Emphasizes simplicity
- Omits interior vapor retarders
- Omits cavity insulation
- Omits sheathing, where possible
- Omits redundant WRB

Maximizes moisture transport
- Omits interior vapor retarders
- Utilizes vapor permeable WRB
- Combines drain plane with rainscreen cavity
- Vapor permeable WRB over exterior insulation

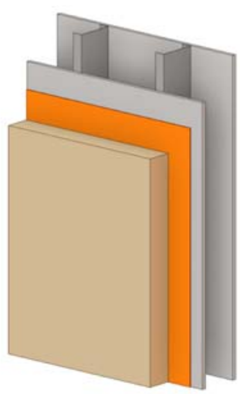
Maximizes Energy Efficiency
- Utilizes exterior CI
- Minimizes thermal bridging
- Prevents convective heat loss
- Adaptable to all climates



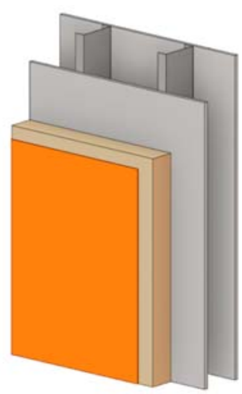
Closing Remarks



A



B



C

Thank You - BTW, please support your local BEC.