Building Enclosures for the Future – Building Tomorrow's Buildings Today

ROXUL BUILDING SCIENCE EDUCATION SERIES
WALSH CONSTRUCTION – MAY 2, 2014

RDH

Session Schedule

- 12:00 – 12:20 – *Lunch*
- 12:20 – 12:35 – Introduction
- 12:35 – 1:30 – Building & Energy Codes in Oregon State
- 1:30 – 2:45 – Wall Assemblies
- 2:45 – 3:00 – *Refreshment Break*
- 3:00 – 4:15 – Conventional Roof Assemblies
- 4:15 – 4:30 – Discussion & Q&A

"***RDH Building Sciences***" is a Registered Provider with ***The American Institute of Architects Continuing Education Systems (AIA/CES)***. Credit(s) earned on completion of this program will be reported to ***AIA/CES*** for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

This program is registered with ***AIA/CES*** for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Copyright Materials

RDH
Making Buildings Better

Learning Objectives

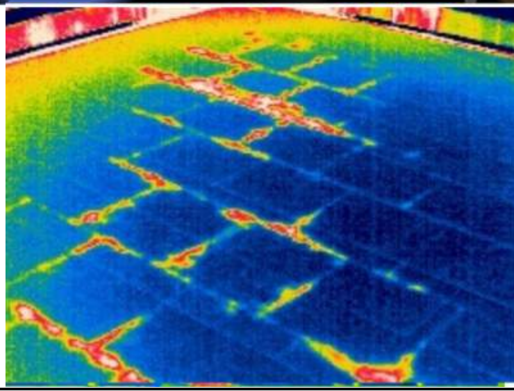
At the end of this program, participants will be able to:

1. Review and understand changes to Oregon Energy Codes that impact building enclosure design strategies, air tightness, and whole building energy efficiency.
2. Understand the design requirements for wall and roof assemblies and how the selection of the right insulation is critical to reliable long-term performance.
3. Learn about several emerging design strategies being used for the construction of highly insulated wall and roof assemblies and how to apply these technologies to projects.
4. Understand the impact that the selection of building enclosure assemblies will have on the space-conditioning and overall energy use of a building.

Introduction

What do you See?

RDH



What do you See?

RDH

What do you See?

RDH

Trends in Building Enclosure Designs

RDH

- Growing trend towards more efficiently insulated building enclosures due to higher energy code targets and uptake of passive design strategies
  - At a point where traditional assemblies being replaced with new ones
  - Seeing more new building materials, enclosure assemblies and construction techniques
  - Greater attention paid to reducing thermal bridging
  - Optimization of cladding attachments for structural and thermal performance
  - Thicker amounts of insulation – particularly in low-slope roofs
  - Measurable improved building enclosure airtightness

What Will be Covered Today

RDH

- Review current & upcoming energy codes in Pacific Northwest
  - Driving improvements in building enclosure energy efficiency & airtightness
  - R-value requirements for walls and roofs
  - Analysis & code compliance tips
- Design strategies for more highly insulated walls
  - Exterior insulation and thermally efficient cladding attachment systems
  - Attachment options and new detailing considerations
- Design strategies for more durable & highly insulated roofs
  - Research demonstrates improvements which can be made in selection of insulation type and insulation strategies

Energy Efficient Building Enclosure Design Fundamentals

RDH

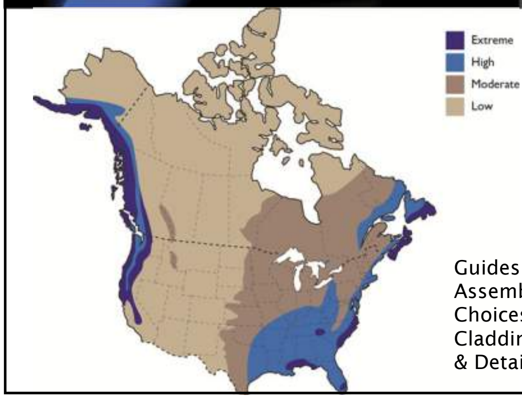
- Thermal insulation continuity & effectiveness – energy code driven
- Airflow control/airtightness – energy code and building code driven
- Control of condensation and vapor diffusion – building code driven
- Control of exterior moisture/rainwater & detailing – building code driven
- Noise & Fire control – building code driven
- **More insulation = less heat flow to dry out moisture**
  - Amount, type and placement of insulations matters, for vapor, air and moisture control
  - Greater need to more robust and better detailed assemblies

Considerations in the Pacific Northwest

RDH

Climate Zones – Rainfall Exposure

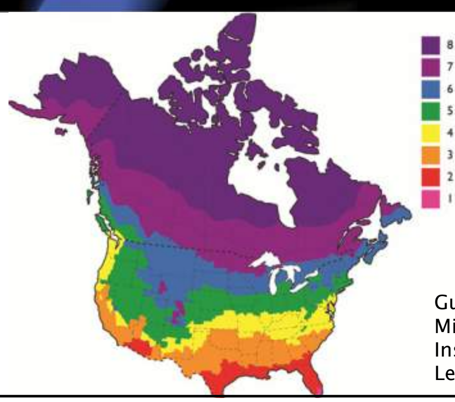
RDH



Guides Assembly Choices, Claddings & Detailing

Climate Zones – Energy Code Classifications

RDH



Guides Minimum Insulation Levels

The Challenge of our Climate

RDH

- → Continue to repair moisture damaged buildings in the Pacific Northwest

What Have We Learned from Past Building Enclosure Failures?

RDH

- → Rainwater penetration causes most problems –poor details (e.g. lack of, poorly implemented, bad materials)
- → Air leakage condensation can cause problems
- → Vapor diffusion can cause wetting, but also allows drying
- → Windows leak and sub-sill drainage and flashings are critical, other details and interfaces also important
- → Insulation inboard of structural elements decreases temperatures which increases risk for moisture damage
- → Watch over-use of impermeable materials in wet locations
- → Durability of building materials is very important
- → Drained & ventilated rainscreen walls work well
- → Unproven materials & new systems can be risky

Balancing Energy, Moisture & Other Drivers

RDH

- → Well insulated building enclosures require careful design and detailing to ensure durability
  - → Balancing materials, cost, and detailing considerations
  - → Cladding attachment – minimize loss of R-value of exterior insulation while providing structure
  - → Shifting insulation to the outside the structure improves performance and durability
- → Well insulated buildings require balancing thermal performance of all components & airtightness
  - → No point super-insulating walls/roofs if you have large thermal bridges - address the weakest links first
- → **Opportunities for both new and retrofit of existing buildings**

Building Enclosure Code and Principles

CODE REVISIONS AND BUILDING SCIENCE FUNDAMENTALS
MAY 2, 2014
DAVID C. YOUNG, P.E.

RDH

Energy Codes – Presentation Outline

- 2014 Oregon Energy Efficiency Specialty Code (OEESC) – Enclosure Updates
- 2012 Washington State and Seattle Energy Code significant differences and where they (we?) are headed next
- Seattle benchmarking requirements and results
- A bit on combustible WRBs

Energy Codes

RDH

- 2012 WSEC
- 2012 SEC
- 2014 OEESC

2014 OEESC Code Scope and Intent

RDH

- 2014 OEESC based on 2010 OESSC
- Intended to clarify and correct 2010 OEESC
- ~~CH 4 – Residential Deleted – see CH 11 ORSC~~
- CH 5 – Commercial Added Air Barrier Requirements from 2012 IECC

Effective Dates

RDH

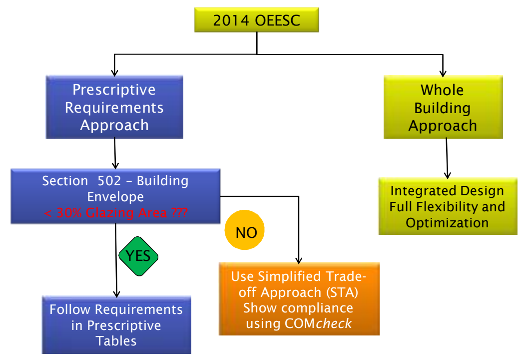
- 2010 OEESC applies now
- 2014 OEESC effective July 1, 2014
- 3-month grace period to September 30, 2014
- 2012 WSEC effective since July 1, 2013
- 2012 SEC effective since December 26, 2013

Oregon Energy Code Compliance

RDH

- Compliance can be demonstrated for commercial and residential portions of commercial construction by:
  - Prescriptive Method (Simple) and COM*check* software
  - Simplified Trade-off Approach (STA) method and COM*check* software (Prescriptive Analysis)
  - Whole Building Approach (WBA) (Performance Analysis)
    - EnergyPlus (New software to improve on DOE2)
    - eQuest

2014 Oregon Energy Efficiency Specialty Code (OEESC)



STA – COM*check* Software

→ States that can use COM*check* to show compliance

Component Performance Approach

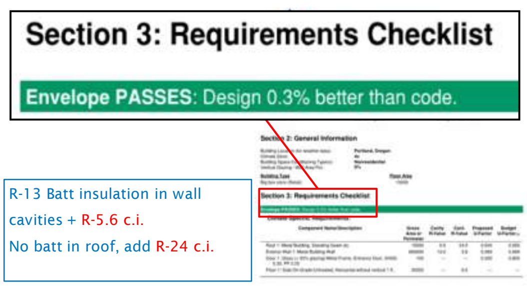
$UA_T = UA_1 + UA_2 + \ldots$

Oregon Energy Code Compliance – COM*check*

→ COM*check* generates compliance forms for both the Prescriptive and STA

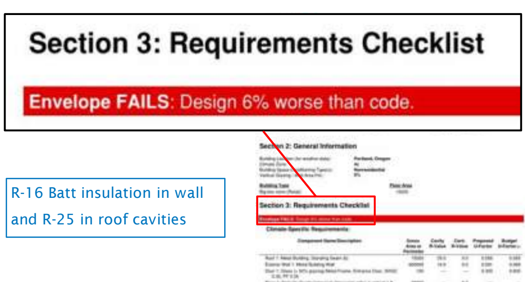
→ Under the WBA path, COM*check* forms should be included to demonstrate the differences between the WBA proposed building and the "budget" building meeting prescriptive requirements

COM*check* Compliance Report



R-13 Batt insulation in wall cavities + R-5.6 c.i.
No batt in roof, add R-24 c.i.

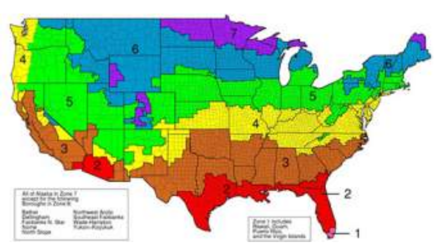
COM*check* Compliance Report



R-16 Batt insulation in wall and R-25 in roof cavities

2014 Oregon Energy Efficiency Specialty Code (OEESC)

→ Maintains US Climate Zone Map (Zones treated equally)
- → Oregon: Marine 4 and 5
- → Washington: Marine 4, 5, and 6



2014 Oregon Energy Efficiency Specialty Code (OEESC)

RDH

- → Building Envelope (Enclosure) Overview
  - → ~~Chapter 4 – Residential Energy Efficiency~~
  - → Chapter 5 – Commercial Energy Efficiency
    - Section 502 – Building Envelope Requirements
    - Section 503 – Building Mechanical Systems
    - Section 504 – Service Water Heating
    - Section 505 – Electrical Power and Lighting Systems
    - Section 506 – Whole Building Approach (WBA)
    - Section 507 – Other Equipment

2014 Oregon Energy Efficiency Specialty Code (OEESC)

RDH

- → Building Envelope (Enclosure) Overview
  - → ~~Chapter 4 – Residential Energy Efficiency~~
  - → Chapter 5 – Commercial Energy Efficiency
    - Section 502 – Building Envelope Requirements ←
    - Section 503 – Building Mechanical Systems
    - Section 504 – Service Water Heating
    - Section 505 – Electrical Power and Lighting Systems
    - Section 506 – Whole Building Approach (WBA)
    - Section 507 – Other Equipment

2014 Oregon Energy Efficiency Specialty Code (OEESC)

RDH

- → Section 502 – Building Envelope Systems
  - → To follow prescriptive approach building must have a maximum of 30% glazing area
  - → 502.1.1– Prescriptive Insulation R-values
  - → 502.1.2 – U-Factor Alternative – Based on assembly
    - U-Factor – (Thermal Transmittance)
    - C-Factor – (Thermal Conductance)
    - F-Factor – (Perimeter Slab-on-Grade)

} Less than or equal to factors in Table 502.1.2

$R_{effective} = R_1 + R_2 + R_3 + \ldots$

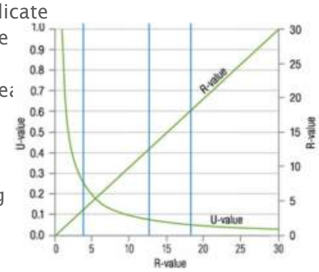
$U_{ASSEMBLY} = 1/R_{effective}$

Must consider effective R-Value of Assembly
ASHRAE Fundamentals Chapters 25-27

R and U Value Review

RDH

- → Lower U-values indicate better performance
- → U-values can be area weighted R-values cannot
- → Law of diminishing returns



2014 Oregon Energy Efficiency Specialty Code (OEESC)

RDH

Table 502.1.1
Building Envelope Requirements, Opaque Assemblies

CLIMATE ZONE	MARINE 4 and 5	
	All Other	Group R
Roofs		
Insulated entirely above deck	R-20ci	R-20ci
Metal Buildings (with R-3.5 thermal blocks)	R-13 + R-13	R-19
Attic and other	R-38	R-38
Walls, Above Grade		
Mass	R-11.4ci	R-13.3ci
Metal building	R-13 + R-5.6ci	R-13 + R-5.6ci
Metal framed	R-13 + R-7.5ci	R-13 + R-7.5ci
Wood framed and other	R-13 + R-3.8ci or R-21	R-13 + R-3.8ci or R-21
Walls, Below Grade		
Below-grade wall	R-7.5ci	R-7.5ci

2012 WSEC and SEC Comparison

RDH

CLIMATE ZONE	2014 OEESC		2012 WSEC		2012 SEC	
	MARINE 4, 5 and 6					
	All Other	Group R	All Other	Group R	All Other	Group R
Roofs						
Insulated entirely above deck	R-20ci	R-20ci	R-30 ci	R-30 ci	R-38 ci	R-38 ci
Metal Buildings (with R-3.5 thermal blocks)	R-13 + R-13	R-19	R-25 + 11Ls	R-25 + 11Ls	R-25 + 11Ls	R-25 + 22Ls
Attic and other	R-38	R-38	R-49	R-49	R-49	R-49
Walls, Above Grade						
Mass	R-11.4ci	R-13.3ci	R-9.5 ci	R-13.3 ci	Varies by Wall Type	Varies by Wall Type
Metal building	R-13 + R-5.6ci	R-13 + R-5.6ci	R-13 + 13 ci	R-13 + 13 ci	R-13 + 13 ci	R-13 + 13 ci
Metal framed	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + 10 ci	R-19 + 8.5 ci	R-13 + 10 ci	R-19 + 8.5 ci
Wood framed and other	R-13 + R-3.8ci or R-21	R-13 + R-3.8ci or R-21	R-21int	R-21int	R-13 + 7.5 ci	R-21 int
Walls, Below Grade						
Below-grade wall	R-7.5ci	R-7.5ci	Same as Above Grade	Same as Above Grade	Same as Above Grade	Same as Above Grade

2014 Oregon Energy Efficiency Specialty Code (OEESC)

Table 502.1.2 - Building Envelope Requirements, Opaque Element, Maximum *U*-Factors

$R_{calculated} = 1/U$

CLIMATE ZONE	MARINE 4 and 5			
	All Other		Group R	
Roofs				
Insulated entirely above deck	U-0.048	R-21	U-0.048	R-21
Metal Buildings	U-0.055	R-18	U-0.055	R-18
Attic and other	U-0.027	R-37	U-0.027	R-37
Walls, Above Grade		R-11.4		R-13.3
Mass	U-0.150	R-6.7	U-0.090	R-11
Metal building	U-0.069	R-14.5	U-0.069	R-14.5
Metal framed	U-0.064	R-15.6	U-0.064	R-15.6
Wood framed and other	U-0.064	R-15.6	U-~~0.051~~ 0.064	R-~~19.6~~ 15.6
Walls, Below Grade				
Below-grade wall	C-0.119	R-8.4	C-0.119	R-8.4

502.2.1.1 Roof Curbs. Portions of curb skylights and equipment above the roof deck shall be insulated with minimum R-5 insulation.
Exception: Skylight curbs included as a component of an NFRC 100 rated assembly shall not be required to be insulated.

2012 WSEC and SEC Comparison

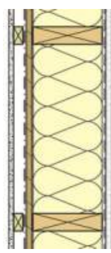
CLIMATE ZONE	2014 OEESC		2012 WSEC		2012 SEC	
	MARINE 4, 5 and 6					
	All Other	Group R	All Other	Group R	All Other	Group R
Roofs						
Insulated entirely above deck	U-0.048	U-0.048	0.034	0.031	0.026	0.026
Metal Buildings	U-0.055	U-0.055	0.031	0.031	0.027	0.027
Attic and other	U-0.027	U-0.027	0.021	0.021	0.021	0.021
Walls, Above Grade		U-0.104 2012 IECC				
Mass	U-0.150	U-0.090	0.104	0.078	0.057	0.057
Metal building	U-0.069	U-0.069	0.052	0.052	0.052	0.052
Metal framed	U-0.064	U-0.064	0.055	0.055	0.055	0.055
Wood framed and other	U-0.064	U-~~0.051~~ 0.064	0.054	0.054	0.051	0.051
Walls, Below Grade						
Below-grade wall	C-0.119	C-0.119	Same as Above Grade	Same as Above Grade	Same as Above Grade	Same as Above Grade

Calculating One-Dimensional R- and U-values

- Appendix A
- ASHRAE Fundamentals
- Thermal Modeling Software (THERM)

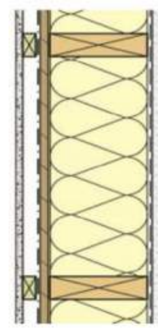
2x6 wood-framed wall with R-19 batts
Effective R value = 16
Effective U value = 0.063 Just meets OEESC U-0.064 max

2x6 metal framed wall with R-19 batts
Effective R value = 9.3
Effective U value = 0.106 (R-value reduced by nearly half!)
Does not meet OEESC U-0.064 max



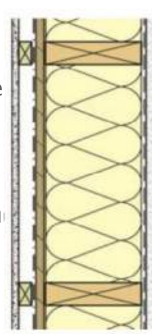
Wood Frame Wall Assemblies

- Assembly
  - ½" gyp
  - 2x6 @ 16" o.c.
  - R-23 high-density mineral fiber insulation
  - ½" sheathing
  - WRB/furring/cladding
- Standard framing factor
  - 77% cavity, 23% framing
- Parallel path calculation method
- U-0.05776 Meets OEESC U-0.064 max
- Does not meet
  - WSEC (U-0.054 max)
  - SEC (U-0.051 max)



Wood Frame Wall Assemblies – Option 1

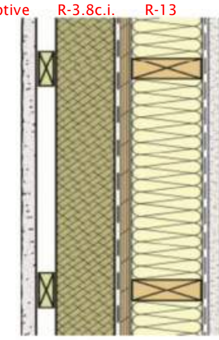
- Assembly
  - ½" gyp
  - 2x8 @ 16" o.c.
  - R-30 high density mineral fibe
  - ½" sheathing
  - WRB/furring/cladding
- Standard framing factor
  - 77% cavity, 23% framing
- Parallel path calculation m
- U-0.0454 (R-22.0)
- Meets
  - WSEC (U-0.054 max)
  - SEC (U-0.051 max)



Wood Frame Wall Assemblies – Option 2

2014 OEESC prescriptive R-3.8c.i. R-13

- Assembly
  - ½" gyp
  - 2x6 @ 16" o.c.
  - R-21 batt
  - ½" sheathing
  - 1" Mineral fiber insulation (R-4.2 ci)
- Standard framing factor
- Parallel path calculation method
- U-0.0464 (R-21.5)
- Meets
  - OEESC (U-0.064 max)
  - WSEC (U-0.054 max)
  - SEC (U-0.051 max)



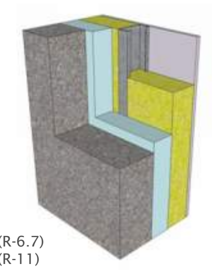
Framing Factors

- Standard framing factors
  - Studs and plates: 0.19
  - Headers: 0.04
  - Insulated cavity: 0.77
- Example
  - 43% framing and 57% insulation

COM*check* assumes:
25% wood framing
75% insulated cavity

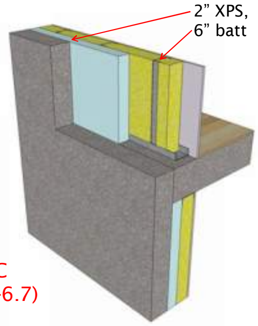
Mass Wall Assemblies – Interior Insulation

- Assembly
  - ½" gypsum
  - 6" steel studs @ 16" o.c.
  - R-20 batt insulation
  - 1.5" XPS continuous insulation
  - 8-inch concrete
  - WRB/furring/cladding
- Standard framing factors
- Heat 3 calculation method
- U-0.050 (R-19.9)
- Required
  - OEESC Commercial: U-0.150 (R-6.7)
  - OEESC Residential: U-0.090 (R-11)
  - WSEC Commercial: U-0.104 (R-9.6)
  - WSEC Residential: U-0.078 (R-12.8)
  - SEC Res. and Comm: U-0.057 (R-17.5)



Mass Wall Assemblies – Interior Insulation

- Exposed peripheral slab edge degrades thermal resistance of interior insulated assembly
- U-0.156 (R-6.4)



Doesn't even meet OEESC Commercial: U-0.150 (R-6.7)

2014 Oregon Energy Efficiency Specialty Code (OEESC)

Table 502.3
Fenestration

Exception: Buildings complying with STA per Section 502.1.3

CLIMATE ZONE	5 AND MARINE 4
Vertical fenestration 30% maximum of above-grade wall	
Fenestration Type	U-Factor
Framing materials other than metal with or without metal reinforcement or cladding	
~~U-factor~~ Fixed, operable, and doors with greater than 50% glazing	0.35
Metal framing with or without thermal break	
Fixed: including curtain wall/storefront ~~U-factor~~	0.45
Entrance door ~~U-factor~~	0.80
All other[a] ~~U-factor~~	0.46
SHGC – all frame types	0.40
Skylights (3% maximum of roof area)	
U-factor	0.60
SHGC	0.40

a. All others includes operable windows, ~~fixed windows~~ and non-entrance doors with greater than 50% glazing.

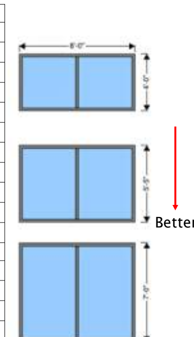
2012 WSEC and SEC Comparison

	2014 OEESC	2012 WSEC	2012 SEC
CLIMATE ZONE	MARINE 4, 5, and 6		
Vertical fenestration maximum % of above-grade wall	30%	30%*	30%*
Fenestration Type	U-Factor		
Framing materials other than metal with or without metal			
~~U-factor~~ Fixed, operable, and doors with greater than 50% glazing	0.35	0.3	0.3
Metal framing with or without thermal break			
Fixed: including curtain wall/storefront ~~U-factor~~	0.45	0.38	0.38
Entrance door ~~U-factor~~	0.8	0.6	0.6
All other[a] ~~U-factor~~	0.46	0.3	0.3
SHGC – all frame types	0.4	0.4	0.35
Skylights			
Maximum % of roof area	3%	3%	5%
U-factor	0.6	0.5	0.45
SHGC	0.4	0.35	0.32

Notes:
*) Washington & Seattle codes allows for a 10% increase in fenestration area (40% max) when daylight strategies conform to Section C402.3.1.1.

Glazing U-Values for Cube

8'x4' Window (86% Glazing)				Frame	
Glazing	Coating	SHGC	COG U-Value	TriFab 451T	Trifab 451UT
Low E, Double, Air	SN 68 SN 54	0.38 0.28	0.29 0.29	0.42	0.38
Low E, Double, Argon	SN 68 SN 54	0.38 0.28	0.23 0.23	0.375	0.34
Low E, IS, Double, Air	SN 68 SN 54	0.36 0.27	0.24 0.24	0.365	0.33
Low E, IS, Double, Argon	SN 68 SN 54	0.36 0.27	0.2 0.2	0.345	0.31
8'x5.5' Window (88% Glazing)				Frame	
Glazing	Coating	SHGC	COG U-Value	TriFab 451T	Trifab 451UT
Low E, Double, Air	SN 68 SN 54	0.38 0.28	0.29 0.29	0.4	0.37
Low E, Double, Argon	SN 68 SN 54	0.38 0.28	0.23 0.23	0.355	0.33
Low E, IS, Double, Air	SN 68 SN 54	0.36 0.27	0.24 0.24	0.345	0.32
Low E, IS, Double, Argon	SN 68 SN 54	0.36 0.27	0.2 0.2	0.33	0.295
8'x7' Window (89% Glazing)				Frame	
Glazing	Coating	SHGC	COG U-Value	TriFab 451T	Trifab 451UT
Low E, Double, Air	SN 68 SN 54	0.38 0.28	0.29 0.29	0.375	0.36
Low E, Double, Argon	SN 68 SN 54	0.38 0.28	0.23 0.23	0.345	0.32
Low E, IS, Double, Air	SN 68 SN 54	0.36 0.27	0.24 0.24	0.34	0.31
Low E, IS, Double, Argon	SN 68 SN 54	0.36 0.27	0.2 0.2	0.315	0.29



§502.4 – Air Leakage

RDH

→ Completely New Section

§502.4 – Air Leakage

RDH

→ NEW! From 2012 IECC:
- → 502.4.1 Air barriers *A continuous air barrier shall be provided throughout the building thermal envelope. The air barriers shall be permitted to be located on the inside or outside of the building envelope, located within the assemblies composing the envelope, or any combination thereof.*
- → 502.4.1.1 Air barrier construction
- → 502.4.1.2 Air barrier compliance options (either)
  - 502.4.1.2.1 Materials,
  - 502.4.1.2.2 Assemblies, or
  - 502.4.1.2.3 Building test
- → 502.4.2 Air barrier penetrations
- → 502.4.3 Air barrier leakage of fenestration and doors

§502.4 – Air Leakage

RDH

→ **502.4.1.1 Air barrier construction**

1. Continuous through all thermal envelope assemblies and joints
2. All joints, seams, material transitions, and penetrations to be sealed. Sealed so as not to dislodge, loosen or impair function to resist pressure differentials from wind, stack effect or mechanical ventilation
3. Recessed lighting fixtures to meet §504.2.8. Similar penetrations through air barrier to be airtight

Exception: Buildings that comply with Section 502.4.1.2.3 (Building Test) need not comply with Items 1 and 3

Caution: Don't ignore Items 1 and 3 and hope test will pass at end

§502.4 – Air Leakage

RDH

→ 502.4.1.2.1 Materials – 0.004 cfm/ft²
- → 3/8" Plywood or thicker
- → 3/8" OSB or thicker
- → ½" XPS, Foil-back Polyiso
- → 1.5" Closed Cell Spray Foam (1.5pcf)
- → 4.5" Open Cell Spray Foam (0.4 to 1.5 pcf)
- → ½" Int. Or Ext. Gypsum Sheathing
- → ½" Cement Board
- → Built-up roofing membrane
- → SBS roofing membrane
- → Fully adhered single-ply membrane
- → 5/8" Portland Cement Plaster
- → Cast-in-Place or Precast Concrete
- → Fully grouted concrete block masonry
- → Sheet Steel or aluminum

§502.4 – Air Leakage

RDH

502.4.1.2.2 Assemblies. Assemblies of materials and components with an average air leakage not to exceed 0.04 cfm/ft2 (0.2 L/s . m2) 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 shall comply with this section. Assemblies listed in Items 1 and 2 shall be deemed to comply provided joints are sealed and requirements of Section C402.4.1.1 are met.

1. Concrete or masonry walls coated with one application either of block filler and two applications of a paint or sealer coating.
2. A Portland cement/sand parge, stucco or plaster minimum ½ inch (12 mm) in thickness.

502.4.1.2.3 Building test. The completed building shall be tested and the air leakage rate of the building envelope shall not exceed 0.40 cfm/ft2 at a pressure differential of 0.3 inches water gauge (2.0 L/s . m2 at 75 Pa) in accordance with ASTM E 779 or an equivalent method approved by the code official.

Materials	0.004 cfm/ft²
Assemblies	0.04 cfm/ft²
Building	0.4 cfm/ft²

Whole building air leakage testing is required in WA…

§502.4 – Air Leakage

RDH

Table 502.4.3
Maximum Air Infiltration Rate For Fenestration Assemblies

Fenestration Assembly	Maximum Rate (cfm/ft²)	Test Procedure
Windows	~~0.20~~0.30	AAMA/WDMA/CSA101/I.S.2/A440 Or NFRC 400
Sliding doors	~~0.20~~0.30	
Swinging doors	~~0.20~~0.30	
Skylights – with condensation weepage openings	0.30	
Skylights – all other	~~0.20~~0.30	
Curtain walls	~~(0.3)~~0.06	NFRC 400 Or ASTM 283 at 1.57 psf (75 Pa)
Storefront glazing	~~(0.3)~~0.06	
Commercial glazed swinging entrance doors	1.00	
Revolving doors	1.00	
Garage doors	0.40	ANSI/DASMA 105, NFRC 400 or ASTM E 283 at 1.57 psf (75 Pa)

2012 WSEC and SEC Comparison

RDH

Fenestration Assembly	2014 OEESC Maximum Rate (cfm/ft²)	2012 WSEC Maximum Rate (cfm/ft²)	2012 SEC Maximum Rate (cfm/ft²)
Windows	~~0.20~~0.30	0.20	0.20
Sliding doors	~~0.20~~0.30	0.20	0.20
Swinging doors	~~0.20~~0.30	0.20	0.20
Skylights – with condensation weepage openings	0.30	0.30	0.30
Skylights – all other	~~0.20~~0.30	0.20	0.20
Curtain walls	~~(0.3)~~0.06	0.06	0.06
Storefront glazing	~~(0.3)~~0.06	0.06	0.06
Commercial glazed swinging entrance doors	1	1	1
Revolving doors	1	1	1
Garage doors	0.40	0.40	0.40

Construction Documents

RDH

103.1 Information on the construction documents. Construction documents shall be of sufficient clarity to indicate the location, nature and extent of the work proposed, and show in sufficient detail pertinent data and features of the building, systems and equipment as herein governed. Details shall include but are not limited to, as applicable, insulation materials and their R-values; fenestration U-factors and SHGCs; system design criteria; mechanical and service water heating system and equipment types, sizes and efficiencies; economizer description; equipment and system controls; fan motor horsepower (hp) and controls; duct sealing, duct and pipe insulation and location; lighting fixture schedule with wattage and control narrative; air sealing details; COM*check* compliance report for the State of Oregon.

→ **Exception:** The code official is authorized to waive the requirements for construction documents, COMcheck reports, or other supporting data if the code official determines these are not necessary to confirm compliance with this code.

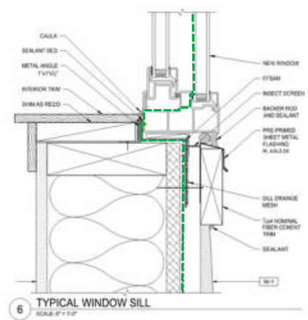
Typical Air Barrier Details

RDH

- Critical at all assembly or system transitions
  - Window to wall interfaces
  - Doors, louvers, other penetrations
  - Parapets
  - At-grade tie-in
  - Expansion joints
  - Balconies
  - Etc.

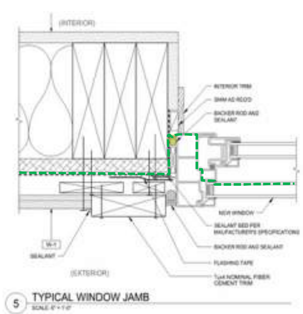
Typical Air Barrier Details

RDH



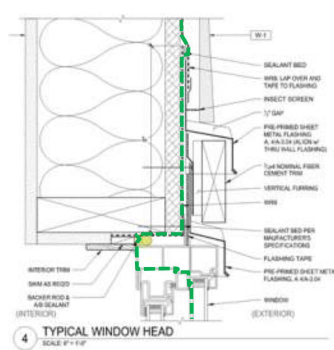
Typical Air Barrier Details

RDH

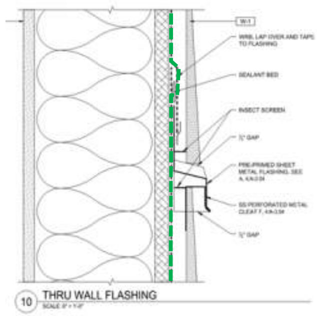


Typical Air Barrier Details

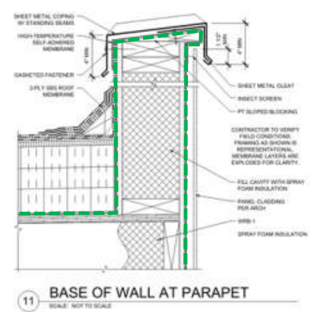
RDH



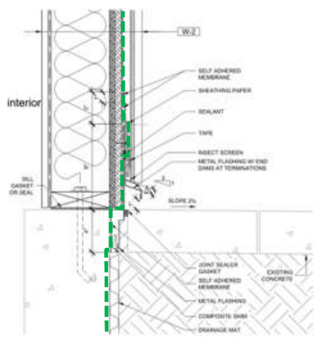
Typical Air Barrier Details



Typical Air Barrier Details



Typical Air Barrier Details

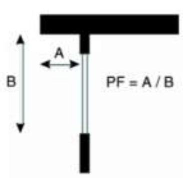


Existing Buildings (Envelope)

- **No significant changes**…
- **Additions, alterations, renovations or repair**
  - New construction parts must comply, but without forcing existing parts to comply
  - Addition will comply if addition alone complies or addition and existing building comply as a single building
- **Exceptions**…

Projection Factor (PF)

- Not specifically addressed in OEESC text, but *is* included as option in COM*check* software
- Included in Washington State Energy Codes
- PF = horizontal distance/vertical distance from bottom of window.

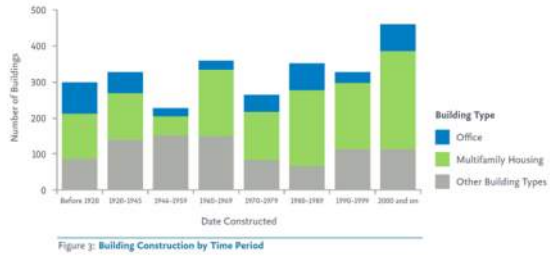


Benchmarking

- 2011/2012 Seattle Building Energy Benchmarking Analysis Report

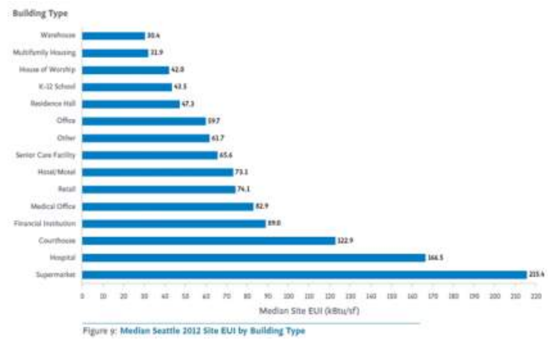
[2] *This report uses the "Site EUI" metric, which represents the total on-site energy use—the most relevant metric for facility managers and owners. Site EUI, however, does not account for the environmental impacts of energy sources. Seattle also uses site EUI because the metrics used by the US EPA to calculate source EUI do not take into account Seattle City Light's carbon-neutrality.*

Energy Use Intensity (EUI)



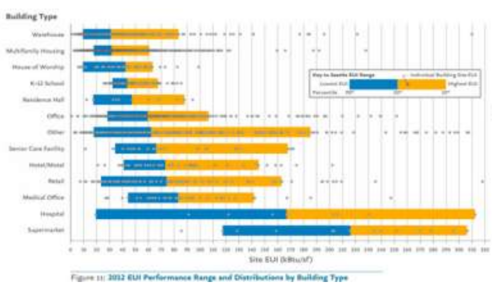
Building Construction by Time Period

Energy Use Intensity (EUI)



Median Seattle 2012 Site EUI by Building Type

Energy Savings Potential



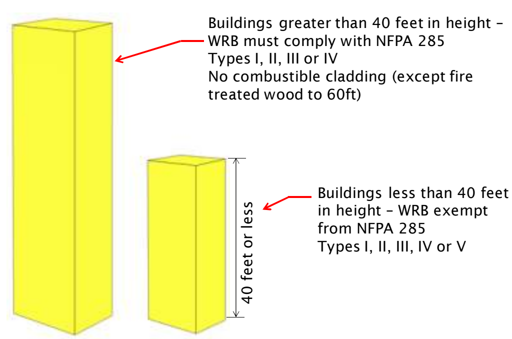
Where is Seattle headed?

- → Triple glazing?
- → Thermal bridging reductions?
- → Focus on existing building stock?
- → Trending towards EUI in lieu of component based codes…
- → Whole building air leakage for OR buildings????

Combustibility – WRBs

- → 2014 Oregon Structural Specialty Code (OSSC)
  - → Chapter 14 – Walls **New Clause**
  - → ***1403.5 Vertical and lateral flame propagation.***
    Exterior walls on buildings of Type I, II, III or IV construction that are greater than 40 feet (12 192 mm) in height above grade plane and contain a ***underline:*** *combustible water-resistive barrier shall be tested in accordance with and comply with the acceptance criteria of NFPA 285.*

Combustibility – WRBs



Combustibility – WRBs

- All states are adopting either this language or they are writing their own language
- Changes for 2015 code are now set
- Any proposed changes now for 2018 IBC code cycle.

Proposed Oregon Wording – 2014 OSSC

- Target effective date, July 1, 2014
- 1403.5 **Vertical and lateral flame propagation.** Exterior walls on buildings of Type I, II, III or IV construction that are greater than 40 feet (12 192 mm) in height above grade plane and contain a combustible water-resistive barrier shall be tested in accordance with and comply with the acceptance criteria of NFPA 285.

Proposed Oregon Wording – 2014 OSSC

- Target effective date, July 1, 2014
- 1403.5 **Vertical and lateral flame propagation.** Exterior walls on buildings of Type I, II, III or IV construction that are greater than 40 feet (12 192 mm) in height above grade plane and contain a combustible water-resistive barrier shall be tested in accordance with and comply with the acceptance criteria of NFPA 285. *For the purpose of this section, fenestration products and flashing of fenestrations shall not be considered part of the water-resistive barrier.*

Proposed Oregon Wording, cont'd

- *1403.5 Exceptions:*
  1. *Walls in which the water-resistive barrier is the only combustible component and the exterior wall has a wall covering of brick, concrete, stone, terra cotta, stucco or steel with minimum thicknesses in accordance with Table 1405.2.*

Proposed Oregon Wording, cont'd

- 1403.5 Exceptions:
  1. Walls in which the water-resistive barrier is the only combustible rior wall ick, tta, stucco hicknesses 1405.2.

Steel (approved corrosion resistant)	0.0149
Stone (cast artificial, anchored)	1.5
Stone (natural)	2
Structural glass	0.344
Stucco or exterior cement plaster	
Three-coat work over:	
Metal plaster base	0.875[b]
Unit masonry	0.625[b]
Cast-in-place or precast concrete	0.625[b]
Two-coat work over:	
Unit masonry	0.5[b]
Cast-in-place or precast concrete	0.375[b]
Terra cotta (anchored)	1
Terra cotta (adhered)	0.25

Proposed Oregon Wording, cont'd

- *1403.5 Exceptions, cont'd:*
  2. *Walls in which the water-resistive barrier is the only combustible component and the water-resistive barrier has a Peak Heat Release Rate of less than 150 kW/m², a Total Heat Release of less than 20 MJ/m² and an Effective Heat of Combustion of less than 18 MJ/kg as determined in accordance with ASTM E1354 and has a flame spread index of 25 or less and a smoke-developed index of 450 or less as determined in accordance with ASTM E84 or UL 723. The ASTM E1354 test shall be conducted on specimens at the thickness intended for use, in the horizontal orientation and at an incident radiant heat flux of 50 kW/m².*

Huh?

This is the proposed wording for the 2015 IBC

Proposed Oregon Wording, cont'd

RDH

- ASTM E84 – **Standard Test Method for Surface Burning Characteristics of Building Materials**
  - Flame spread index and smoke-developed index are commonly published performance characteristics found in many product datasheets
- ASTM E1354 – **Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter**
  - "Cone Calorimeter Test"
  - Where is this information published????

Washington State Wording

RDH

- Went into effect July 1, 2013
- 1403.5 **Vertical and lateral flame propagation.** Exterior walls on buildings of Type I, II, III or IV construction that are greater than 40 feet (12 192 mm) in height above grade plane and contain a combustible water-resistive barrier shall be tested in accordance with and comply with the acceptance criteria of NFPA 285.
  - ***Exception:*** *Walls that contain less than 500 g/m² combustible material and where the water-resistive barrier has a flame spread index of 25 or less and a smoke-developed index of 450 or less as determined in accordance with ASTM E 84 or UL 723.*

Seattle Building Code Wording

RDH

- Summer, 2013
- ~~1403.5 **Vertical and lateral flame propagation.** Exterior walls on buildings of Type I, II, III or IV construction that are greater than 40 feet (12 192 mm) in height above grade plane and contain a combustible water-resistive barrier shall be tested in accordance with and comply with the acceptance criteria of NFPA 285.~~

City of Seattle deleted 1403.5 completely

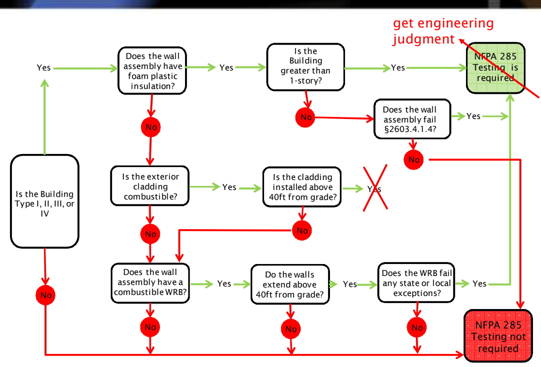
NFPA 285 – Tested Assemblies

RDH

- Manufacturer information is building….

2012 NFPA 285 – Decision Tree

RDH



Next Generation High R-value Wall Assemblies

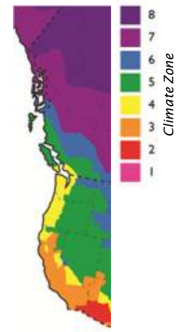
High R-value Walls – Outline

- Effective R-values & Thermal Bridging
- Alternate High R-value Wall Assemblies
- Evolution of Cladding Attachment Systems
- Alternate Cladding Attachment Systems
- Masonry Supports

From Energy Codes to Next Generation

RDH

- Energy codes outline minimum thermal performance criteria based on climate zone
  - Energy Standards & International Codes: ASHRAE 90.1, IECC
  - WSEC 2012, Washington State & SEC 2012, City of Seattle
  - OEESC 2010 – Oregon State
- Energy codes in Pacific Northwest are some of most stringent but are also the best implemented in North America
- Wall & Roof (R-value/U-values) very important part of compliance
- Effective R-values considered



Effective R-values

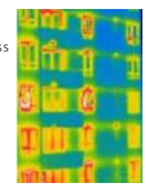
RDH

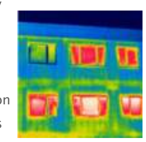
- All Energy codes now consider effective R-values (vs insulation nominal R-values)
- **Nominal R-values** = Rated R-values of insulation which do not include impacts of how they are installed
  - For example R-20 batt insulation or R-10 rigid insulation
- **Effective R-values** include impacts of insulation installation and all thermal bridges
  - For example nominal R-20 batts within steel studs becoming ~R-9 effective, or in wood studs ~R-15 effective

Thermal Bridging

RDH

- Thermal bridging occurs when a more conductive material (e.g. metal, concrete, wood etc.) bypasses a less conductive material (insulation)
- Minimizing thermal bridging is key to energy code compliance and an energy efficient building
  - Balance of good window performance and appropriate window to wall ratio
  - Use of exterior continuous insulation with thermally improved cladding attachments
  - Minimizing the big thermal bridges
- Energy codes have historically focused on *assembly R-values*, however more attention is now being placed on *interface and detail R-values*, and cladding attachments
- Also impacts comfort, condensation, and mold





From Code Minimum to Next Generation

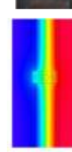
RDH

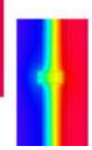
- In Pacific Northwest - minimum energy code R-value targets are in range of:
  - R-15 to R-25 effective for walls
  - R-25 to R-50 effective for roofs
  - R-2 to R-4 for windows
- Green or more energy efficient building programs including Passive House, R-value targets in range of:
  - R-30 to R-50+ effective for walls
  - R-40 to R-60+ effective for roofs
  - R-6+ for windows
- Other drivers – air-tight, thermal comfort, passive design, mold-free

Thermal Analysis of Effective R-values

RDH

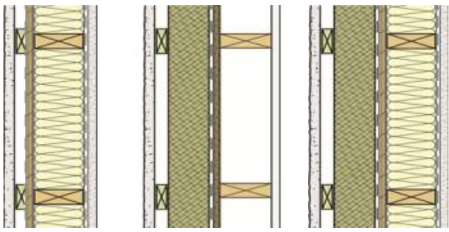
- Effective R-values of building enclosure assemblies & details can be determined by:
  - Hand methods – simple wood frame walls, not suitable for many assemblies/details
  - Laboratory (Guarded hot-box testing) – good for confirmation, expensive and not efficient for design/analysis purposes
  - Two-dimensional finite element thermal modeling – not accurate for modeling discrete or intermittent elements such as clips, ties, or fasteners
  - Three-dimensional finite element thermal modeling – most accurate and cost effective. Calibrated with laboratory testing to improve accuracy.





Getting to Higher R-values - Walls

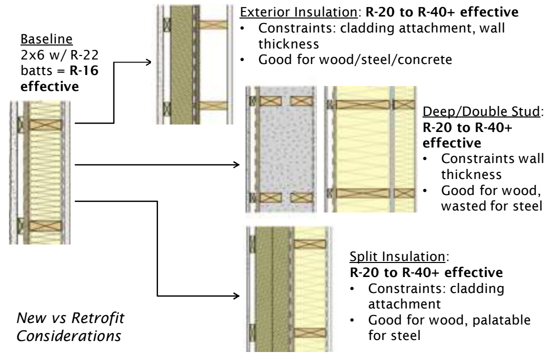
RDH



Interior Insulation | Exterior Insulation | Split Insulation

Getting to Higher R-values - Walls

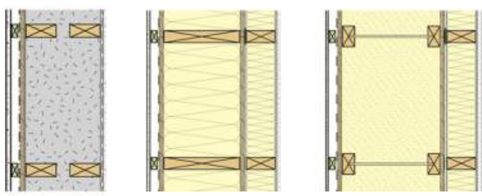
RDH



Double/Deep Stud Insulated Walls

RDH

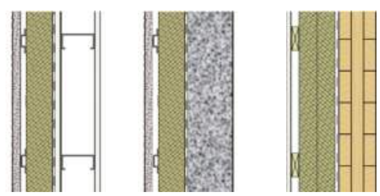
- Double 2x4/2x6 stud, single deep 2x10, 2x12, I-Joist etc.
- Common wood-frame wall assembly in many passive houses (and prefabricated highly insulated walls)
- Inherently at a higher risk for damage if sheathing gets wet (rainwater, air leakage, vapor diffusion) – due to more interior insulation



Exterior Insulated Walls

RDH

- Insulation outboard of structure and control layers (air/vapor/water)
- Thermal mass at interior where useful
- Cladding attachment biggest source of thermal loss/bridging
- Excellent performance in all climate zones – But is not the panacea, can still mess it up

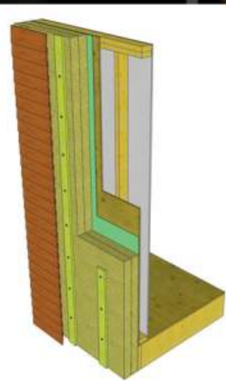


Steel Stud | Concrete | Heavy Timber (CLT)

Key Considerations - Exterior Insulation Assemblies

RDH

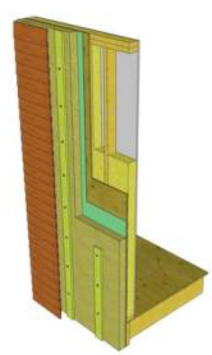
- Key Considerations:
  - Cladding attachment
  - Wall thickness
- Heat Control: Exterior insulation (any type)
- Air Control: Membrane on exterior of structure
- Vapor Control: Membrane on exterior of structure
- Water Control: Rainscreen cladding, membrane on exterior of structure, surface of insulation



Key Considerations - Split Insulation Assemblies

RDH

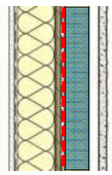
- Key Considerations:
  - Exterior insulation type
  - Cladding attachment
  - Sequencing & detailing
- Heat Control: Exterior and stud space Insulation (designed)
- Air Control: House-wrap adhered/sheet/liquid membrane on sheathing, sealants/tapes etc. Often vapor permeable
- Vapor Control: Poly or VB paint at interior, plywood/OSB sheathing
- Water Control: Rainscreen cladding, WRB membrane, surface of insulation



Split Insulation – Exterior Insulation Choice

RDH

- Rigid exterior foam insulations (XPS, EPS, Polyiso, closed cell SPF) are vapor impermeable (in thicknesses of 2"+)
  - Is the vapor barrier on the wrong side?
  - Does the wall have two vapor barriers, can it dry?
  - How much insulation should be put outside of the sheathing?
    - More is always better, but is there room? Budget?
- Semi-rigid/rigid mineral wool insulation is vapor permeable and address these moisture concerns
- Vapor permeance properties of WRB/air barrier membrane is also very important

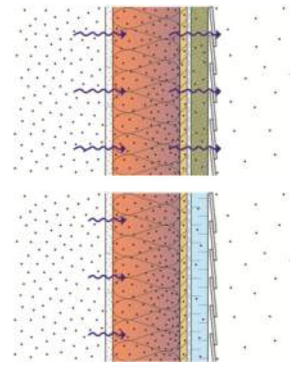


But Why?

RDH

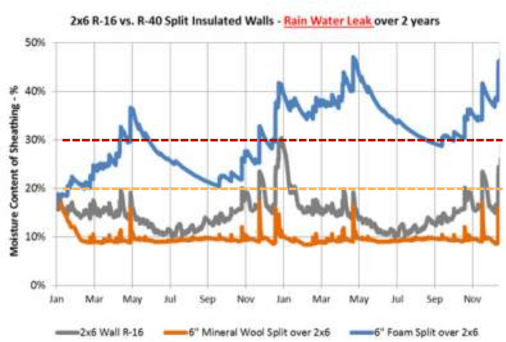
Vapor diffusion drying allowed through mineral wool insulation

Vapor diffusion drying restricted by foam plastic insulation on outside



Split Insulation and Moisture Risk Assessment

RDH



Side by Side Drying Test – Vapour Open vs Closed

RDH

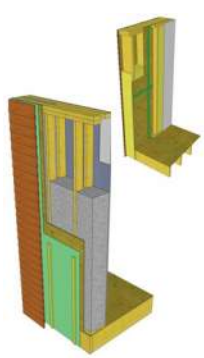
Plywood Behind XPS – wet for 8 weeks

Plywood Behind Mineral Wool – dried within 8 weeks

Key Considerations – Double Stud/Deep Stud

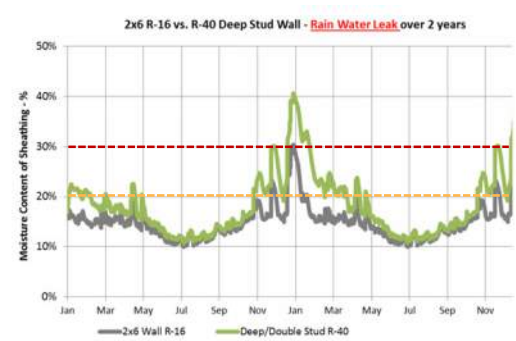
RDH

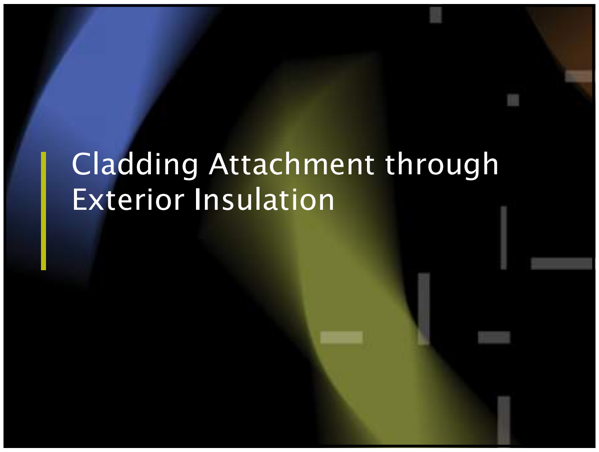
- Key Considerations:
  - Air-sealing
  - Rainwater management/detailing
- Heat Control: Double stud cavity fill insulation(s) – dense-pack cellulose, fiberglass, sprayfoam
- Air Control: House-wrap/membrane on sheathing, poly, airtight drywall on interior, OSB/plywood at interior, tapes, sealants, sprayfoam. *Airtightness on both sides good*
- Vapor Control: Poly, smart vapour retarder, VB paint or OSB/plywood at interior
- Water Control: Rainscreen cladding, WRB at house-wrap/membrane, flashings etc.



Deep/Double Stud and Moisture Risk Assessment

RDH




Cladding Attachment through
Exterior Insulation


Cladding Attachment & Exterior Insulation
RDH
→ Exterior insulation is only as good as the cladding attachment strategy
→ How to achieve true continuous insulation (ci) performance?
→ What attachment system works best?


Background – Exterior Insulation Drivers
RDH


Background – Exterior Insulation Drivers
RDH
Pre-Rehabilitation – Stud Insulated, Lots of Thermal Bridging
Post-Rehabilitation – Exterior Membrane & Fully Exterior Insulated


Trial Exterior Insulation Rehab - Late 1990s
RDH


Trial Exterior Insulation Rehab – Late 1990s
RDH

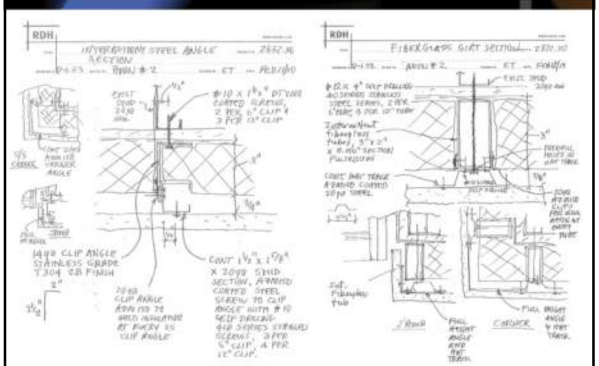
Trial Split Insulated Assembly

Trial Split Insulated Assembly

Lessons Learned About Indoor Humidity & Drying

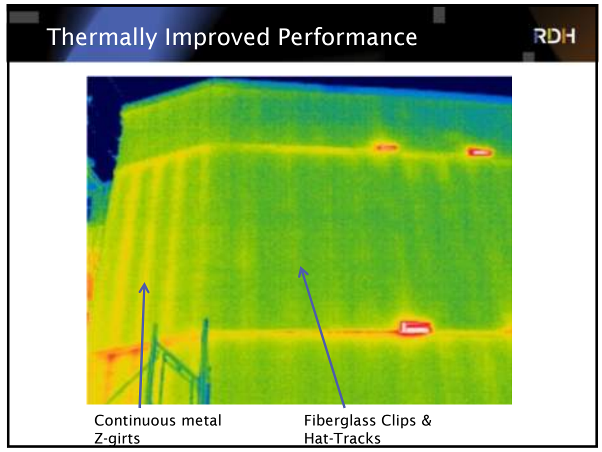
Evolution of Exterior Girt Cladding Attachments

Trial Thermally Improved Cladding Attachments



Trial Thermally Improved Cladding Attachments


Low-Conductivity Cladding Supports
RDH
Blueskin


Thermally Improved Performance
RDH
Continuous metal Z-girts
Fiberglass Clips & Hat-Tracks


Cladding Attachment & Detailing Considerations
RDH


Evolution of Exterior Insulation Approaches
RDH

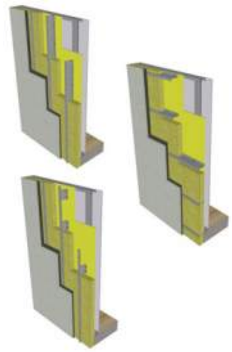

Evolution of Exterior Insulation Approaches
RDH
10/22/2012


Evolution: Bullitt Center Walls
RDH
→ 5-storey structure w/ steel, timber, & concrete
→ Living Building Challenge
→ R-value design target up to R-25 effective for steel framed wall assembly (Minimum code R-18.2)
→ Within a 6" steel stud frame wall structure
→ Tasked with coming up with innovative cladding attachment to meet ambitious target

Bullitt Center – Exterior Wall Analysis

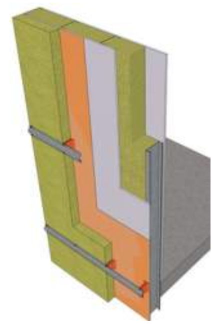
RDH

- Expectation to be cost effective, buildable and minimize wall thickness
- Available various Z-Girt & Metal Clip options evaluated with thermal modeling
  - None could achieve R-25 target, closest was to use expensive stainless steel clips
  - Modeling identified opportunity to improve performance with non-conductive fiberglass clip



Bullitt Center – Exterior Wall Assembly

RDH



- Metal panel cladding
- 1" horizontal metal hat tracks
- 3 ½" semi-rigid mineral fiber (R-14.7) between 3 ½" fiberglass clips (16" x 48" spacing)
- Fluid applied vapor permeable WRB/air barrier on gypsum sheathing
- 6" mineral fiber batts (R-19) between 6" steel studs (outboard of slab edge)
- Gypsum drywall

- **Effective R-value R-26.6**

Bullitt Center – Exterior Wall Construction

RDH

Choosing a Cladding Attachment System

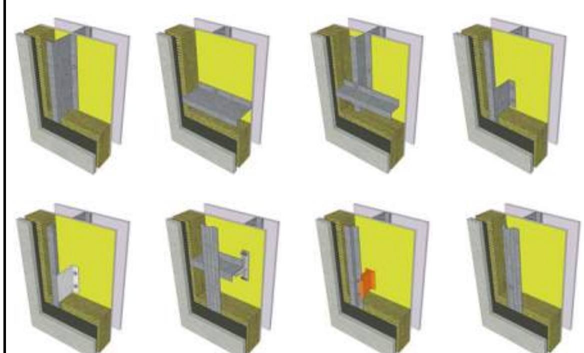
Exterior Insulation & Cladding Attachment Considerations

RDH

- Cladding weight & gravity loads
- Wind loads
- Seismic loads
- Back-up wall construction (wood, concrete, steel)
  - Attachment from clip/girt back into structure (studs, sheathing, or slab edge)
- Exterior insulation thickness
- Rigid vs semi-rigid insulation
- R-value target, tolerable thermal loss?
- Ease of attachment of cladding – returns, corners
- Combustibility requirements

Many Alternate Attachment Options

RDH

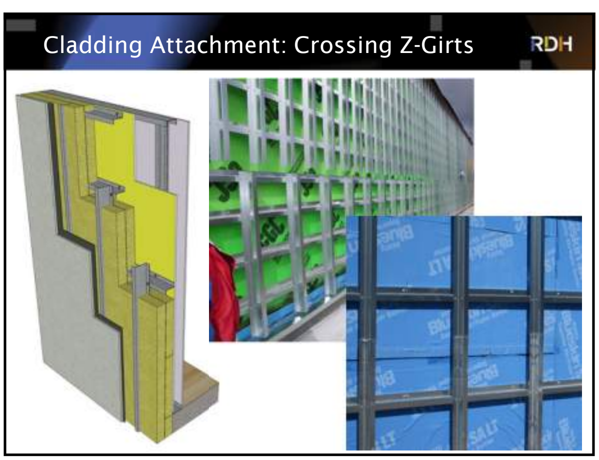



Cladding Attachment: Continuous Wood Framing

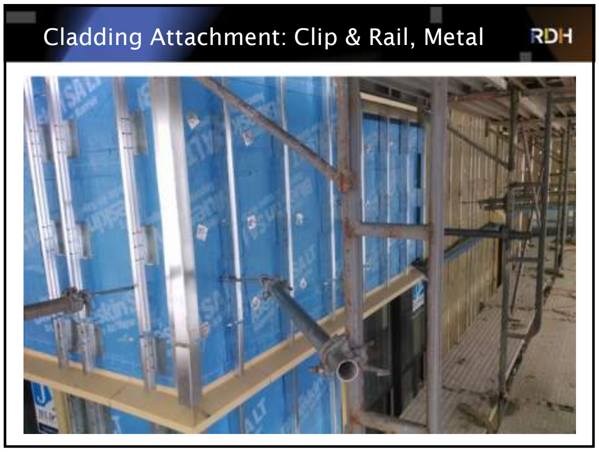

Cladding Attachment: Vertical Z-Girts


Cladding Attachment: Horizontal Z-Girts

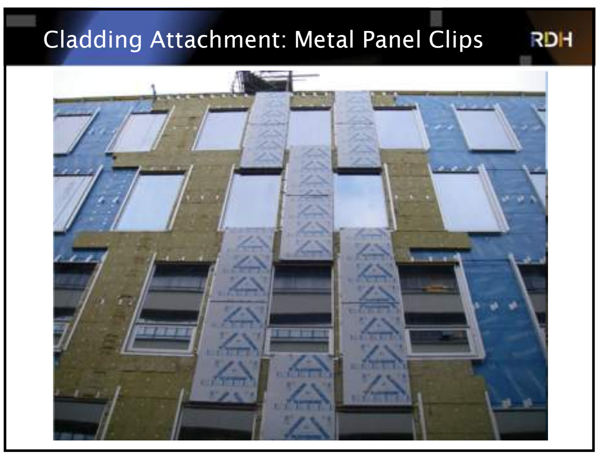

Cladding Attachment: Diagonal Z-Girts


Cladding Attachment: Crossing Z-Girts


Cladding Attachment: Clip & Rail, Metal

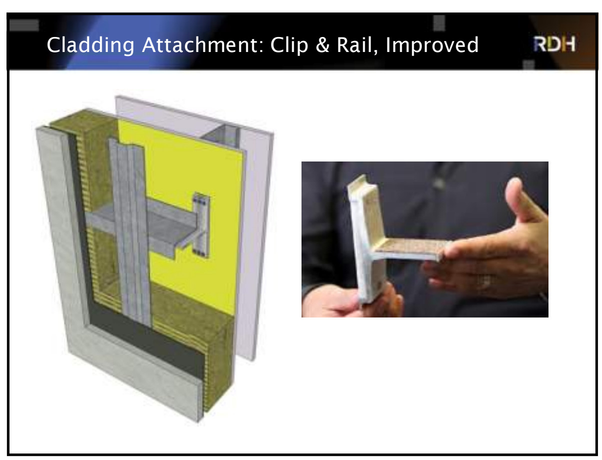

Cladding Attachment: Clip & Rail, Metal
RDH


Cladding Attachment: Clip & Rail, Metal
RDH


Cladding Attachment: Metal Panel Clips
RDH

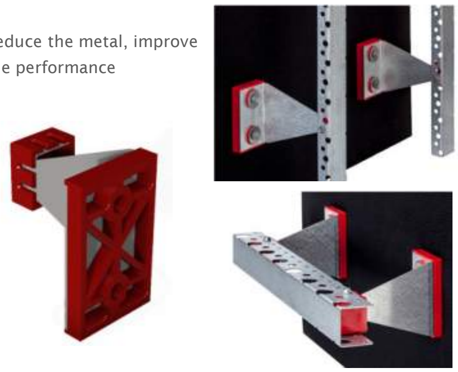

Cladding Attachment: Clip & Rail, Improved
RDH


Cladding Attachment: Clip & Rail, Improved
RDH

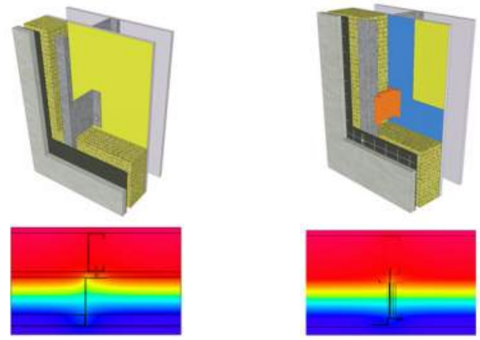

Cladding Attachment: Clip & Rail, Improved
RDH

Cladding Attachment: Clip & Rail, Improved

→ Reduce the metal, improve the performance



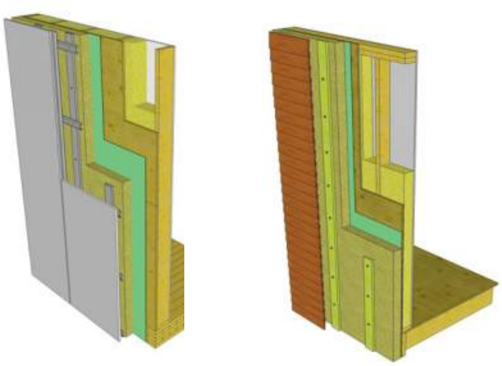
Cladding Attachment: Clip & Rail, Non-Conductive



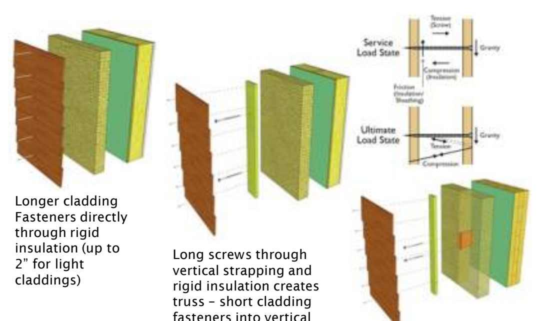
Cladding Attachment: Clip & Rail, Non-Conductive

Cladding Attachment: Clip & Rail, Non-Conductive

Cladding Attachment: Screws through Insulation



Cladding Attachment: Screws through Insulation

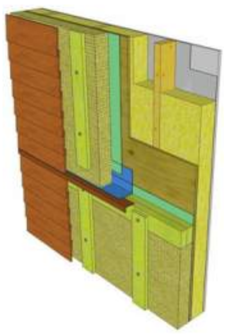


Longer cladding Fasteners directly through rigid insulation (up to 2" for light claddings)

Long screws through vertical strapping and rigid insulation creates truss – short cladding fasteners into vertical strapping

Rigid shear block type connection through insulation, short cladding fasteners into vertical strapping

Screws through Insulation: Shear Blocks



- With heavier weight claddings – may consider shear blocks to limit deflection and creep
  - Not necessary with light-weight claddings
- Shear block material:
  - Continuous or intermitted wood blocks, metal clips etc.

Cladding Attachment: Screws through Insulation

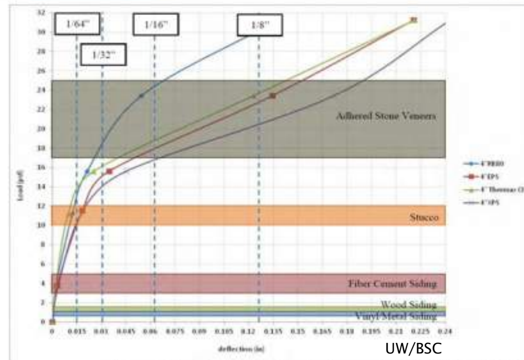


Figure 9: Short term deflection testing results (4" thick insulation)

Cladding Attachment: Screws through Insulation

Cladding Attachment: Screws through Insulation

Cladding Attachment: Screws through Insulation

Cladding Attachment: Screws through Insulation

Screws through Insulation - Corners

RDH

Screws through Insulation - Corners

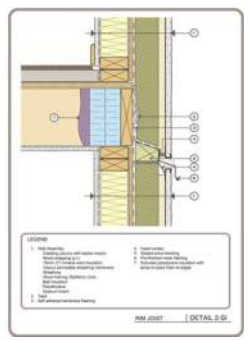
RDH

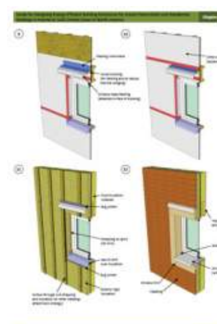
Screws through Insulation – Corners & Details

RDH

Other Considerations - Flashings

RDH





Screws through Insulation – Details!

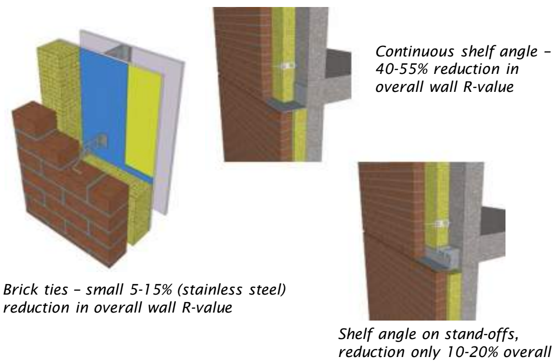
RDH

→ New Roxul Comfortboard IS & CIS Guides out soon

In Other Areas of the World - EIFS

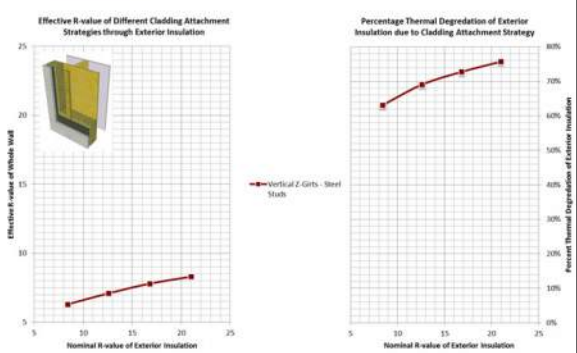
RDH

Cladding Attachment: Masonry Ties & Shelf Angles

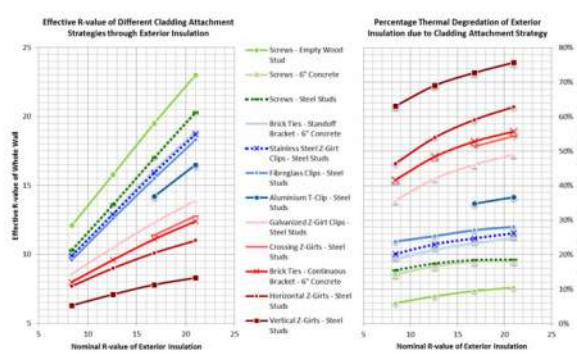


Cladding Attachment: Masonry

Thermal Comparison of Options



Thermal Comparison of Options



Cladding Attachment Recommendations

Substrate / Cladding Type	Wood Backup (OSB/Plywood)	Steel Stud Backup	Concrete or Concrete Block Backup
Light weight *(up to fiber cement panels, <10psf)*	Clip & Rail good Screws good	Clip & Rail good Screws okay, but difficult to hit stud	Clip & Rail good Screws can be difficult to install
Medium weight *(stucco, cultured stone, 10-30 psf)*	Clip & Rail good Screws with shear block or engineered	Clip & Rail good Screws with shear block or engineered	Clip & Rail good Screws can be difficult to install
Heavy weight *(Masonry, Stone Panels, >30 psf)*	Gravity supports, anchors & engineered connections only	Gravity supports, anchors & engineered connections only	Gravity supports, anchors & engineered connections only

Questions & Discussion

→ rdhbe.com

RDH

Next Generation Conventional Roofs:
Measured Benefits of Light to Dark Roofing Membranes & Alternate Insulation Strategies

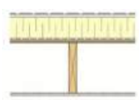
Conventional Roofs – Outline

- → Conventional Roofing Designs and Current Issues
- → Conventional Roofing Field Monitoring and Research Program
- → Measured Insulation Performance
- → Selecting Roofing Membrane Color and Insulation Strategy for Optimum Energy Efficiency
- → Case Studies

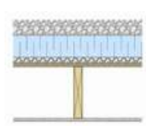
Refresher: Low Slope Roof Types

RDH

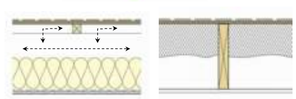
- → Conventional



- → Protected Membrane (Inverted)



- → Vented/Unvented (Compact)

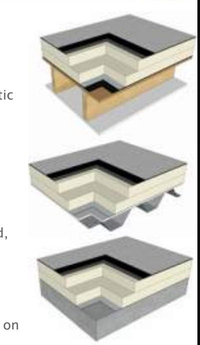


Seattle Code Requires R-30 to R-40

Refresher: Conventional Insulated Roofs

RDH

- → Most common low-slope roof application in North America
- → Insulation installed above structure, protected by roofing membrane - Insulation is typically foam plastic (polyiso, EPS), though mineral fiber also used
- → Roofing membrane is exposed to temperature, UV, traffic – needs to be durable
- → Roof slope typically achieved by tapered insulation unless the structure is sloped
- → Attachment of membrane/insulation can be: adhered, mechanically attached, loose laid ballasted, or combination
- → Wood, concrete, or steel structure substrate
- → Air barrier and vapour control layer below insulation on top of structure (depending on climate/design)



Current Issues With Conventional Roofs

RDH

- → Roofing membrane issues
  - → Two ply vs single ply systems, different membrane types
  - → Details!
- → Insulation movement – Thermally induced
  - → Causes membrane ridging and stresses
  - → More movement with thicker amounts of insulation (becoming more common) and certain insulation types
  - → More movement in roofs with darker colored membranes
- → Insulation movement - Long term shrinkage, expansion, contraction
  - → Gaps between insulation boards, induced membrane stresses
- → Moisture trapped in insulation and roof assembly during wetting during construction or from small leaks in-service
  - → Becoming more common to install leak detection monitoring within conventional roofs and find this out – what to do about it? How to adjust monitoring?

Membrane Ridging & Insulation Movement

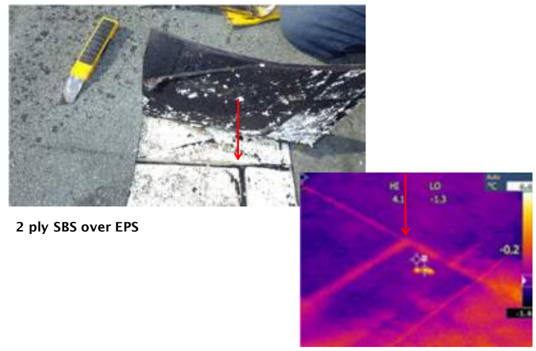
RDH

TPO over gypsum board and polyiso

SBS over wood fiberboard and XPS

Membrane Ridging & Insulation Movement

Membrane Ridging & Insulation Movement



2 ply SBS over EPS

Membrane Ridging & Insulation Movement

2 ply SBS over ISO over EPS taper

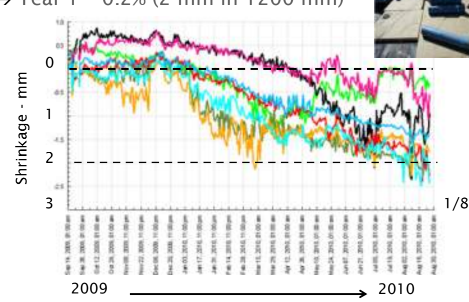
Insulation Shrinkage

Insulation Shrinkage Study

- Polyiso has had a reported history of board shrinkage – both initial and long-term
  - Related to manufacturer, mix, temperature, moisture, and age
  - Results in gaps between the insulation boards and induces stresses introduced into roof membranes
- Past monitoring shows varying amounts of ongoing shrinkage – primarily influenced by age of product when installed

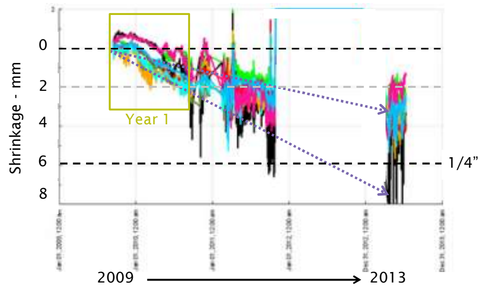
Polyiso Shrinkage Monitoring Study

- Year 1 – 0.2% (2 mm in 1200 mm)



Polyiso Shrinkage Monitoring Study

→ Year 4 – 0.2% to 0.7% (2-8 mm in 1200 mm)



Roof Membrane Color Considerations

- Roof membrane or ballast color (solar absorptivity) influences surface temperature
  - **Darker colors** (more absorptive, less reflective) results in higher temperatures, more assembly movement and membrane stress, higher cooling loads, lower heating loads
  - **Lighter colors** (less absorptive, more reflective) results in lower temperatures, less assembly movement and membrane stress, lower cooling loads, higher heating loads
- Balance needed between membrane durability, assembly movement, heating and cooling loads
- Programs such as LEED have points for use of highly reflective roofs regardless of energy implication and local climate.
- Long term impacts and soiling of light colored roofs

Conventional Roofing Field Monitoring Study

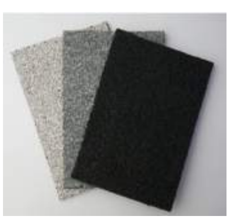
Guiding Purpose of the Study – Why?

- Quantify performance of different colors of exposed roof membrane (white, grey, black)
  - What impact does LEED have on roof energy performance
- Quantify performance differences of stone wool, polyiso and hybrid insulation combinations
- Quantify combined impact of membrane color and insulation strategy
- Observe impact of the long-term soiling of white SBS roofs
- Monitor long-term shrinkage/movement of insulation and relative humidity/moisture levels within insulation
- Laboratory testing of material properties we didn't know

- While Certain materials used for Phase 1 of study – key findings are applicable to all membrane & insulation types

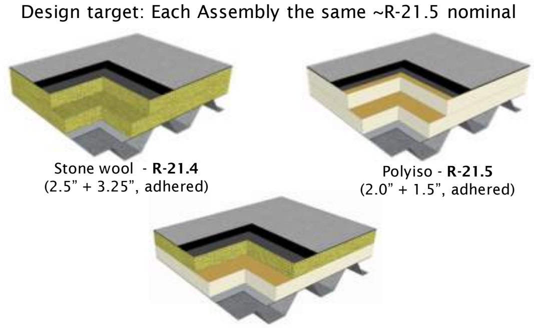
Roof Membrane Colors

- 3 different 2-ply SBS roof membrane cap sheet colors (white reflective, grey, black)



3 Different Insulation Strategies

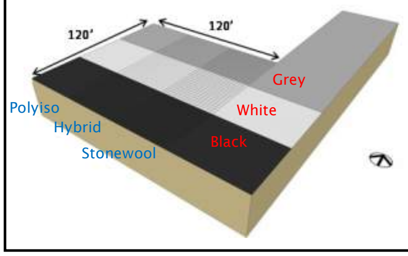
Design target: Each Assembly the same ~R-21.5 nominal



Insulation and Cap Sheet Layout

RDH

- 9 unique roof test areas, each 40' x 40' and each behaving independently
- Similar indoor conditions (room temperature) and building use (warehouse storage)



Sensor Selection and Installation

RDH

- Temperature
- Heat Flux
- Relative Humidity
- Moisture Detection
- Displacement
- Solar Radiation

Temperature

Solar Radiation

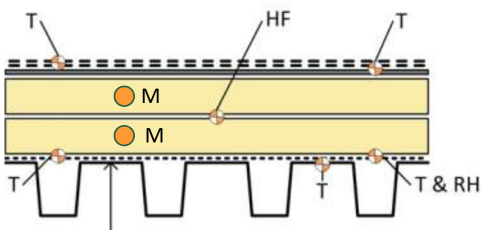
Heat Flux

Relative Humidity & Moisture Detection

Displacement

Sensor Positioning

RDH



T- Temperature
RH- Relative Humidity
HF – Heat Flux
M - Displacement

Roof and Sensor Installation

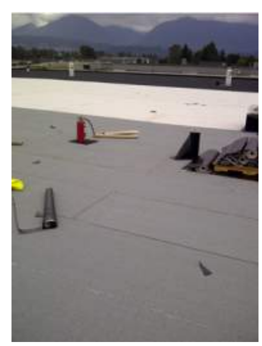
RDH

Roof and Sensor Installation

RDH

Roof and Sensor Installation

RDH



Measured Insulation Performance

My Most Common Designer Question Lately: What R-value is My Insulation?

RDH

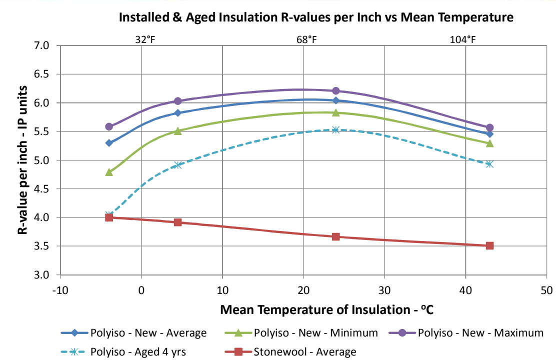
Laboratory Testing of Insulation R-values

RDH

- 3rd Party ASTM C518 thermal transmission material testing performed as part of monitoring study
  - Polyiso and stone wool insulation removed from site + aged 4 year old polyiso samples from prior research study
  - Wanted to know actual R-value as installed and temperature impacts to calibrate sensors
- Testing performed at mean insulation temperatures from 25, 40, 75, and 110˚F to develop R-value vs temperature relationships

Laboratory Testing of Project Insulation

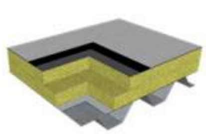
RDH



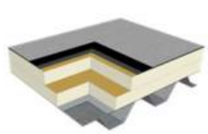
Applying Laboratory Testing to the Field

RDH

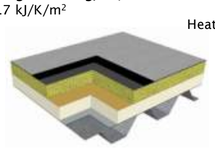
- Design R-values for each assembly ~R-21.5



Stone Wool -2.5" + 3.25", Weight 26.7 kg/m², Heat Capacity – 22.7 kJ/K/m²



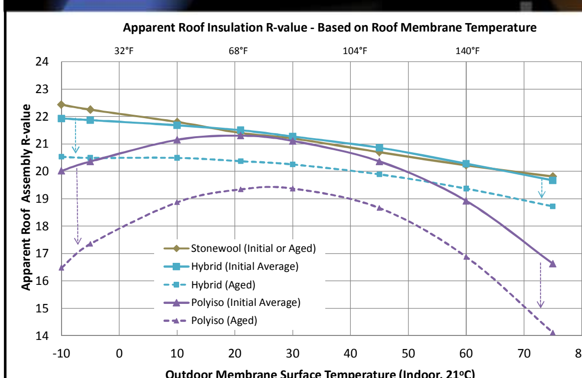
Polyiso - 2.0" + 1.5", Weight 4.6 kg/m², Heat Capacity – 6.8 kJ/K/m²



Hybrid – 2.5" Stone wool + 2.0" Polyiso, Weight 14.3 kg/m², Heat Capacity – 13.7 kJ/K/m²

Varying R-value of Field Roof Assemblies

RDH

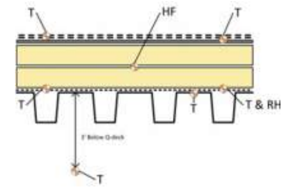


Field Monitoring Results

Field Monitoring Results

RDH

- Monitoring from first 18 months shown today
- Plan is to continue monitoring for 3+ years to look at long-term trends and aging
- Data shown for:
  - Insulation Movement
  - Heat Flux
  - Temperature
  - Moisture



Visual Observations and Monitoring

RDH

- Visual indication (webcam) to observe roof getting soiled over time
- Solar Radiation & Reflected Radiation to observe change over time of relative reflectivity – small change so far in field of membrane

Visual Observations and Monitoring

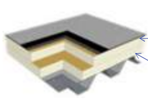
RDH

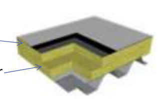
At installation

1 year after installation

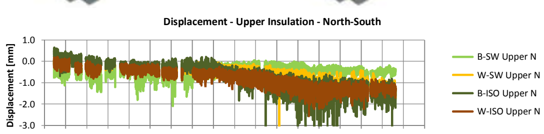
Insulation Movement to Date

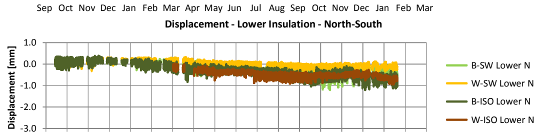
RDH





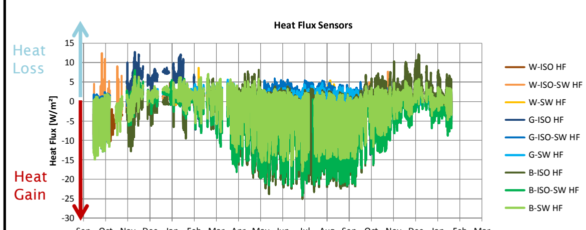
Black & White Cap sheet only





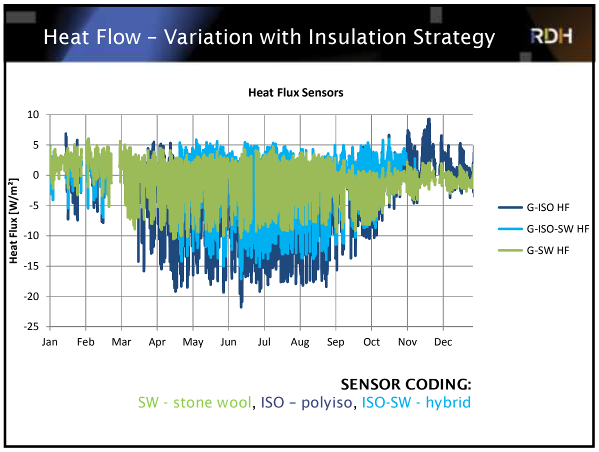
Heat Flux Data – Heat Loss vs Gain

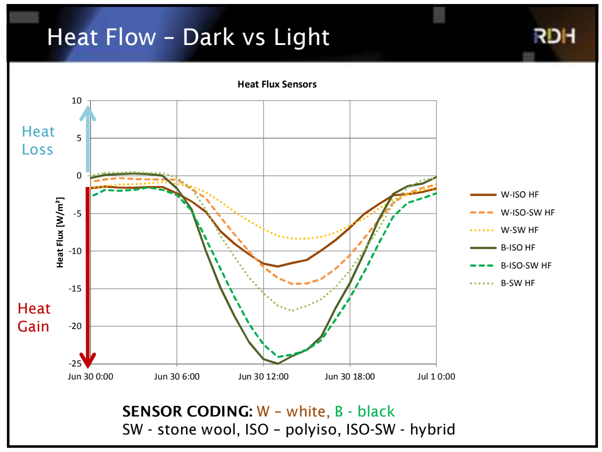
RDH

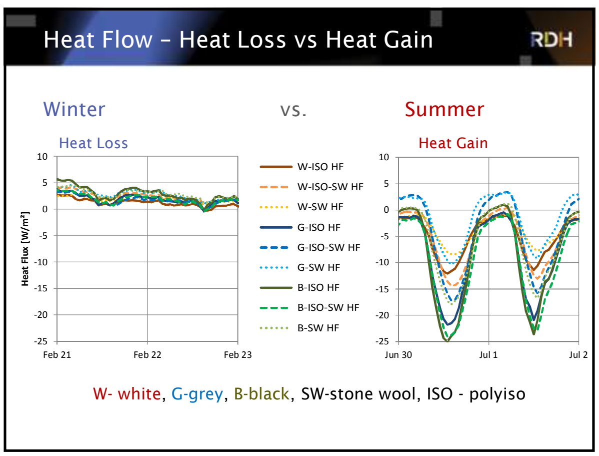


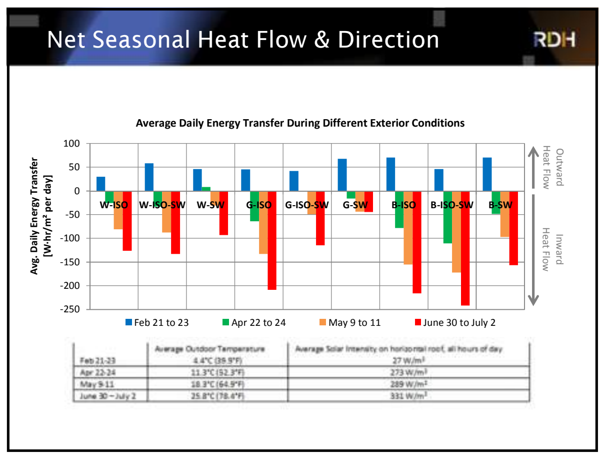
1 W/m² = 0.32 Btu/hr/ft²

SENSOR CODING: W – white, G – grey, B - black
SW - stone wool, ISO – polyiso, ISO-SW - hybrid

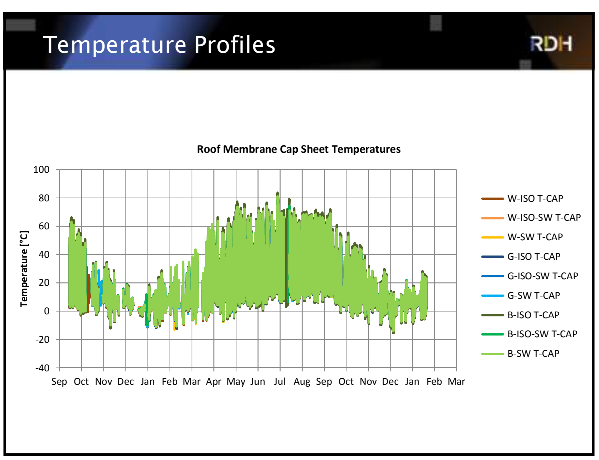


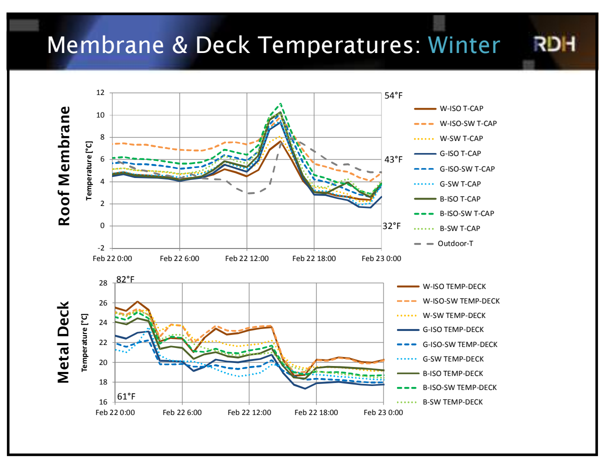




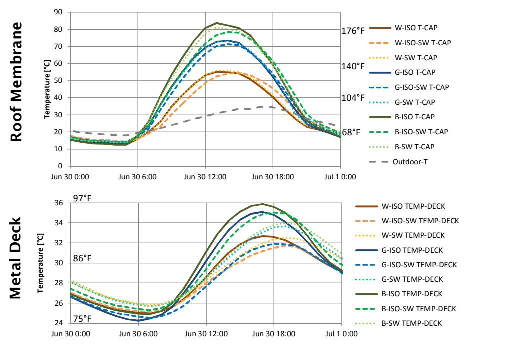


	Average Outdoor Temperature	Average Solar Intensity on horizontal roof, all hours of day
Feb 21-23	4.4°C (39.9°F)	27 W/m²
Apr 22-24	11.3°C (52.3°F)	273 W/m²
May 9-11	18.3°C (64.9°F)	289 W/m²
June 30 – July 2	25.8°C (78.4°F)	331 W/m²

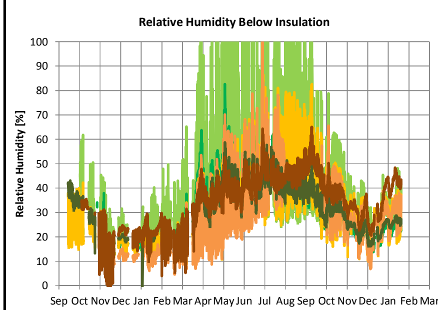




Membrane & Deck Temperatures: Summer

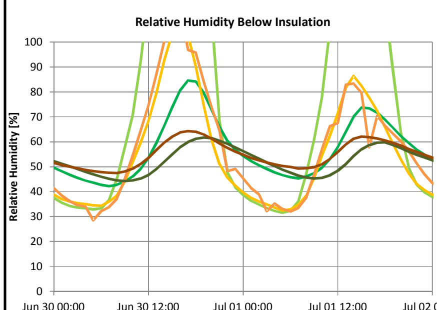


Relative Humidity Trends Below Insulation



All roofs constructed under dry summer conditions, no rain – dry to start

Relative Humidity Trends Below Insulation



All roofs constructed under dry summer conditions, no rain – dry to start

Relative Humidity Impact on Roof?

September 26, 2013 – Clear and Cool at 7 am – air temperature 4˚C/39˚F

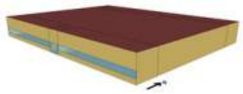
Optimizing Membrane Color and Insulation Strategy for Energy Efficiency

Energy Consumption and Membrane/ Insulation Design

- Calibrated energy modeling used to compare roof membrane color/solar absorptivity & insulation strategy
  - White, Grey or Black Roof Membrane
  - Polyiso, Stone wool, or Hybrid insulation approach
    - Stone wool has lower R-value/inch but higher heat capacity and higher mass
    - Polyiso has a higher R-value/inch (varies with temperature) and has a lower heat capacity and lower mass
    - Hybrid approach has stone wool **over top** of polyiso which moderates temperature extremes of polyiso insulation – **makes polyiso perform better**

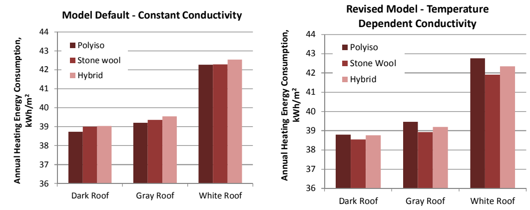
Energy Consumption and Membrane/Insulation Design

- Energy modeling performed for a **commercial retail building** *(ASHRAE building prototype template)*
- Results calibrated with temperature/heat-flux data from monitoring study
- Input temperature dependant & aged R-values into energy model – base R-20 roofs
- Help to select the optimum insulation and membrane color combination for energy efficiency



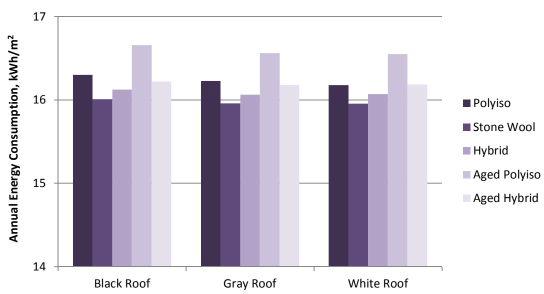
Energy Modeling of Temperature Dependant Insulation R-values

- Total Energy Consumption includes, walls, windows, air leakage, slab, +roof
  - Heating energy for Climate Zone 4/5 (Vancouver) shown here, R-20 insulation

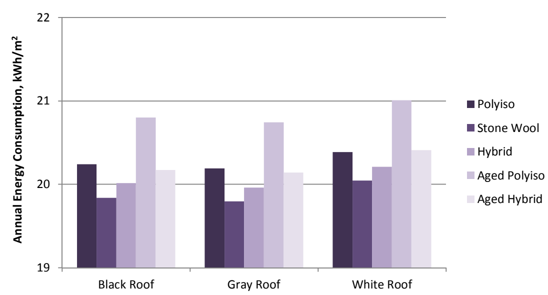


- Input lab measured temperature dependant insulation R-value for polyiso and stone wool into energy model
  - Impact of temperature dependant R-value is significant enough that should be accounted for
  - Results in different design rankings of lowest to highest energy consumption

Most Energy Efficient Combination: Seattle

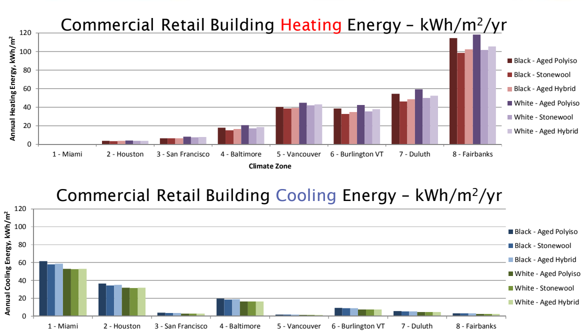


Most Energy Efficient Combination: Portland

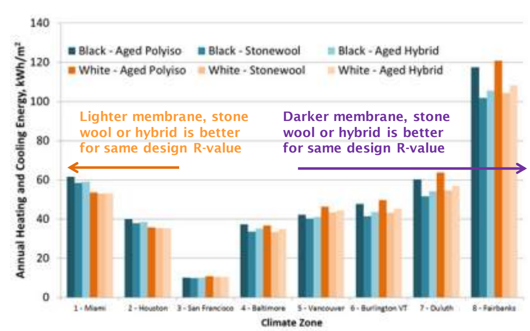


Gray in PDX is optimal

Most Energy Efficient Roofing Combination?



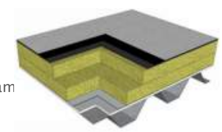
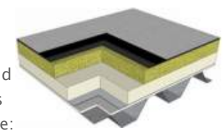
Most Energy Efficient Roofing Combination?



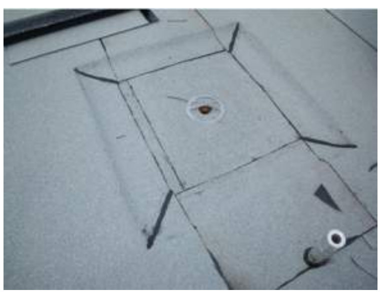
Case Studies

Stone Wool Insulation in Conventional Roofing

- R-value of stone wool is R-3.7/inch compared to a R-4 to R-6/inch for polyiso and R-4/inch for EPS
  - Need thicker stone wool to achieve sam R-value as polyiso in design
- If polyiso kept closer to indoor temperatures, then it has a higher effective R/inch (closer to LTTR)
  - Insulate the Polyiso!
- Hybrid insulation provides good blend of material properties and economics
- Tapered insulation packages available: EPS, Polyiso, or Stone wool

Case Study 1



- 2-ply SBS torched to 2" stone wool over 2" Polyiso (adhered)

Case Study 2

- 2-ply SBS torched to 2" stone wool, over 2" Polyiso, over tapered polyiso (mechanically attached)

Case Study 3

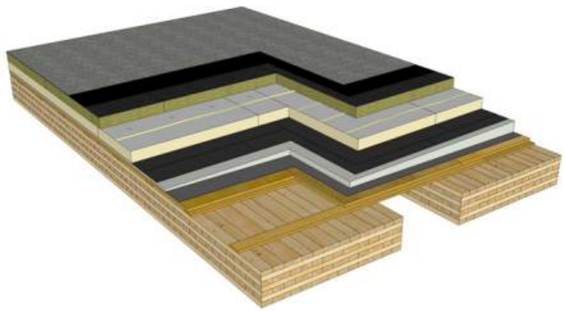
- 2-ply SBS torched to 2" stone wool over tapered polyiso (adhered)

Case Study 4

- 2-ply SBS torched to 1" stone wool with asphalt facer adhered to 2" stone wool adhered to EPS taper package, mechanically fastened

Case Study 5

RDH



Case Study 5

RDH

Designer and Roofing Contractor Feedback

RDH

- Stone wool insulation easy and fast to install. Heavier than EPS/polyiso but doesn't blow away
- Stone wool insulation lays flat and takes up uneven surfaces, tight board installation, very few gaps compared to rigid foam.
- Stone wool is softer than polyiso and potentially softens during construction from foot traffic – not issue in open field areas, but compression can occur in high traffic areas prior to covering – can address with extra asphalt protection board overlay.
- Thicker insulation build-up for stone wool compared to polyiso due to R-value differences, may be an issue where roof height is at a premium or could be issue during re-roof around existing doors and curbs etc.
- Watch mechanical fasteners without a protection board.
- Adhesive with stone wool must be applied and set-in quickly before foam expands. Slightly different process than with EPS/polyiso

Summary – Key Points

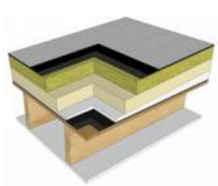
RDH

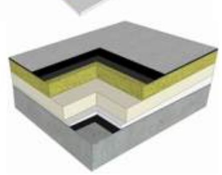
- Research and Field Monitoring Study Findings
  - Design R-value may change in service – all types of insulation are affected to varying degrees – Is not Static
  - In addition to design R-value - heat capacity and latent moisture transfer within insulation has an impact on temperatures and energy transfer
  - Entrapped moisture will ping-pong around more in stonewool than polyiso – RH fluctuations normal
  - Optimization of heating and cooling based on roof membrane color and insulation strategy suggested
  - Careful selection of insulation strategy and membrane colour will have a positive impact on roof assembly performance

Recommended Conventional Roofing Strategies for Energy & Durability

RDH

- Design to provide good balance of cost, thickness, & performance (energy, durability, membrane life)
- Roof Membrane – grey or other neutral color for northern climates, light in south
- Adhered system with stone wool insulation as top layer (30-50% of total insulation R-value)
- Layer of polyiso (below staggered) joints with taper package
- Self adhered/torched sheet air/vapour barrier membrane (temporary roof) over substrate
- Adhered layers preferred instead of mechanically attached, where possible to balance cost





This concludes The American Institute of Architects Continuing Education Systems Course

Presentation Created & Delivered by:

RDH Making Buildings Better

Graham Finch , Dipl.T, MASc, P.Eng
Principal, Building Science Research Specialist
RDH Building Sciences Inc. Seattle/Portland
gfinch@rdhbe.com www.rdhbe.com

Seminar Sponsored by:

ROXUL The Better Insulation


Questions & Discussion
→ rdhbe.com
RDH