Is Your Envelope "Effective"?

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BCBEC Luncheon
January 29, 2009

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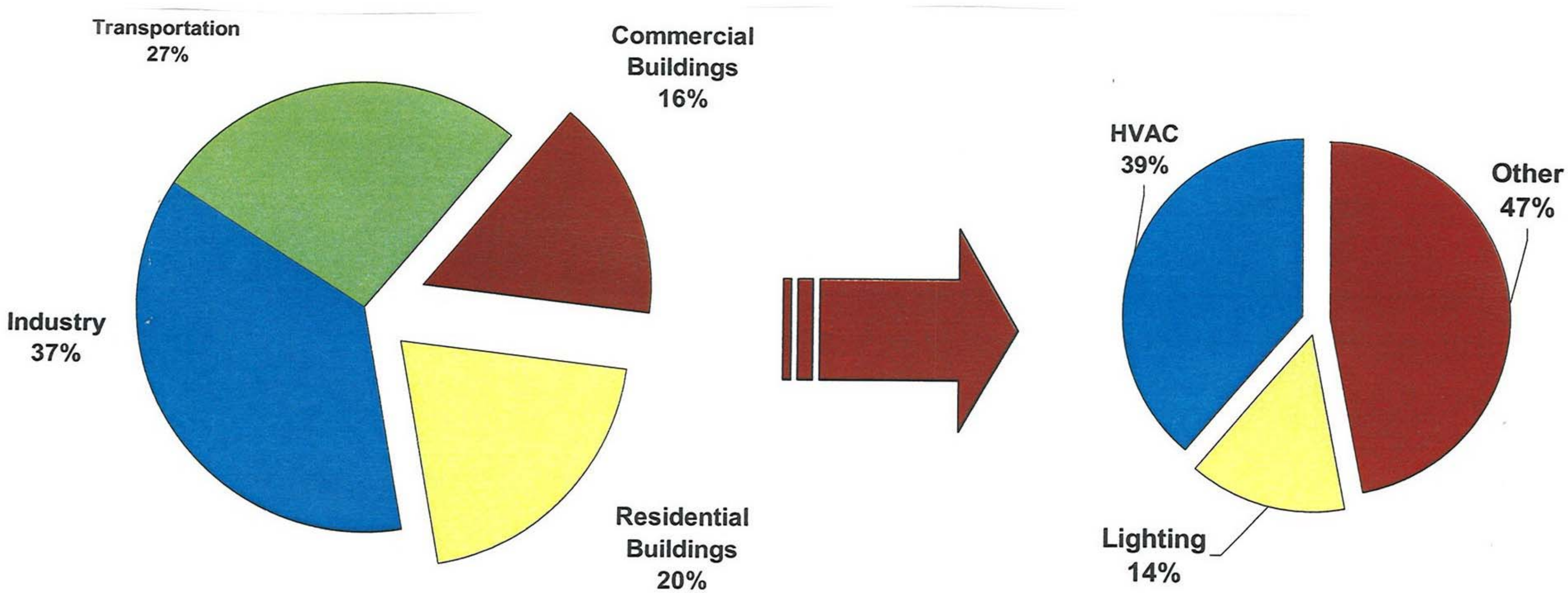
Goals for this Presentation

- Why we might be concerned with heat loss through the envelope (U-value or “Effective” R-value)?
- Why create a catalogue of effective thermal resistances of building envelope details?
- Which details should be catalogued and how do you manage the variations?
- How do you present the information so it can be easily understood by the entire design team?
- What procedure should you follow to determine the effective thermal resistance?

Why Do We Care?

- Government, the public, and our clients are asking for higher levels of thermal resistance.
- Typical North American buildings use 400 $Kwh/m^2/yr$
- German standards call for < 100 $Kwh/m^2/yr$
- North American energy codes will likely continue to tighten minimum requirements of the building envelope
- New regulations require less heat loss through the envelope
- Energy conservation is a big part of LEED

Energy Consumption in Buildings



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Recent Regulatory Changes

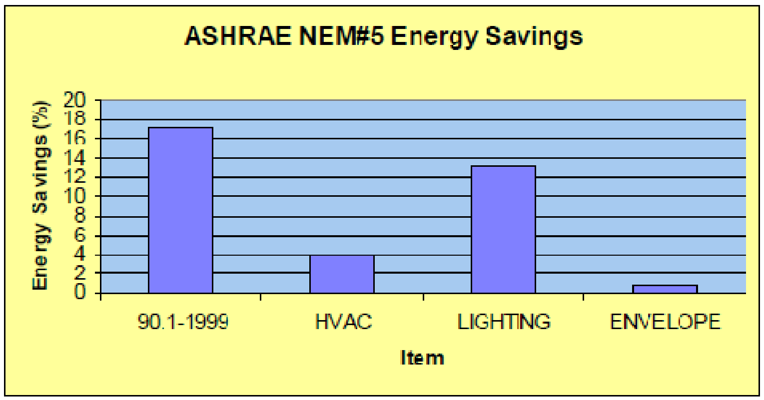
- BC Green Building Code
- All buildings to meet ASHRAE 90.1 – 2004 and in Vancouver ASHRAE 90.1 – 2007
- or for buildings under 5 storeys:
  - Meet prescription table 10.2.1.1.A (basically R20 walls and R28/R40 roofs) or
  - Prove equivalency through computer modeling or
  - Meet or exceed Energuide Rating 77

Recent Code Changes

- Implement Energy Efficiency Standards for Buildings by 2010
  - A new unified B.C. "Greening Building Code" has been developed over the last year with industry, professional, and community representatives
  - The new green building code will implement the highest energy efficiency standards in Canada, which will result in buildings in B.C. costing less to heat and reduce impacts on the environment

How will Energy Codes Evolve?

NEM #5 - SAVINGS ESTIMATES BY SYSTEM, FROM 1989

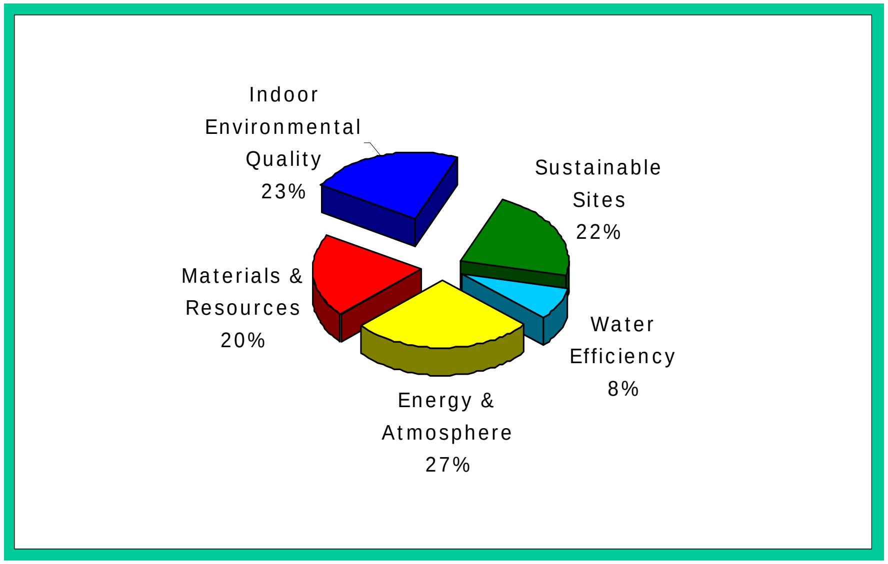


Addendum Type	90.1-2004 (from 2001)	90.1-2001 (from 1999)
Administrative	4	2
Envelope	1	9
Mechanical	17	13
Lighting/Power	7	8
ECB	3	2
Total Addenda	32	34

- Minimum requirements
- Net Zero Buildings?
- ASHRAE 90.1 is on three year cycles
- Objective is to save energy relative to the previous version
- Is there still low hanging fruit?

LEED and Energy

- Succeeding beyond the code minimums
- LEED works on a basis of awarding “points” for meeting particular performance requirements
- Although points can be earned in many ways, optimizing energy performance (EAp.1 & EAc1) represents a significant amount



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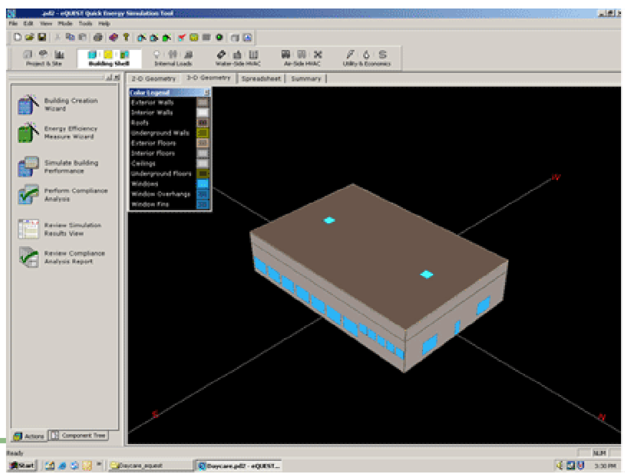
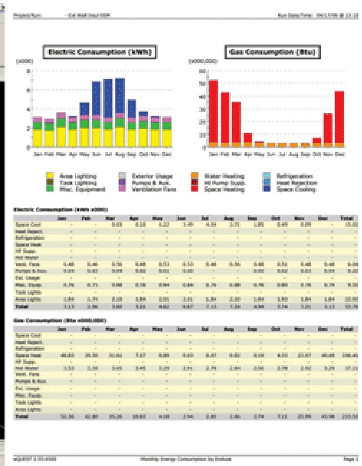
LEED and Energy cont.

- As a prerequisite (EAp.1) you must:
  - Reduce energy consumption by 25% over the MNECB reference building, or
  - Reduce design energy cost by 18% over the reference building built to ASHRAE 90.1-1999
- Up to an additional 10 points are available for exceeding the minimum.

- Compliance shall be demonstrated using whole-building simulations





HOWEVER, THE RULE OF MODELING IS

GARBAGE IN = GARBAGE OUT

SO WHAT VALUES DO YOU PUT IN YOUR MODEL?

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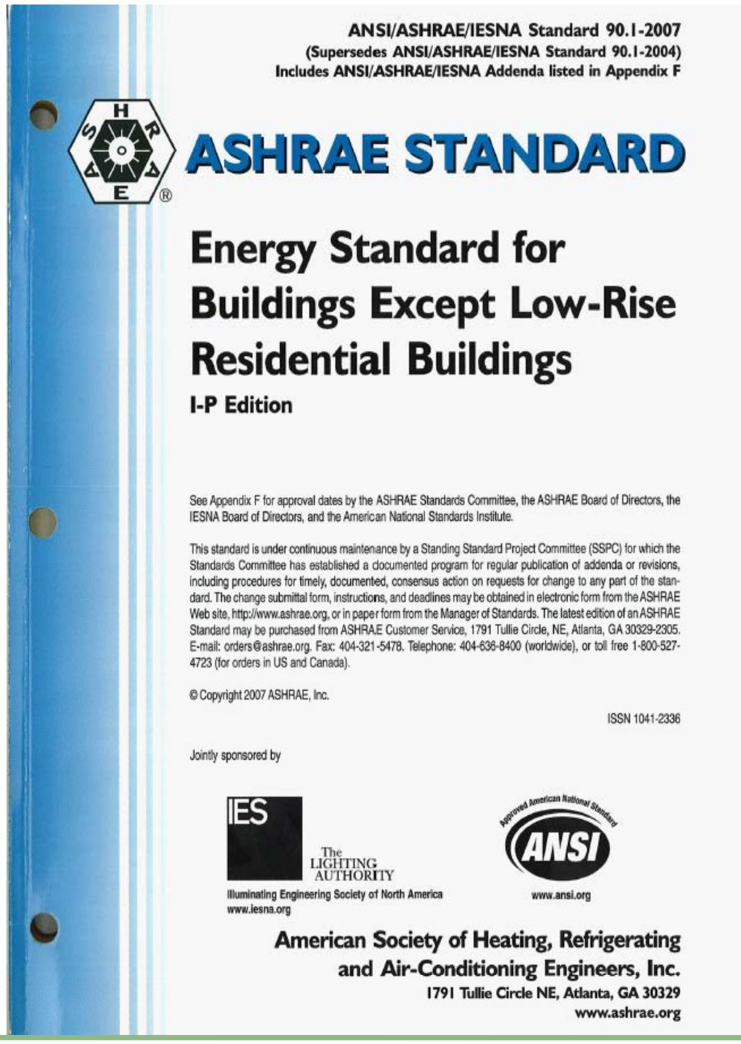
How do we benefit from all this attention to “effective” R-Value?

Suddenly, knowing a lot about emerging technologies became sexy at cocktail parties.

Designing an "Effective Envelope"

- Roofs
- Below Grade Walls and slabs
- Glazing & Windows
- Opaque portions of walls

LEED and ASHRAE 90.1



ANSI/ASHRAE/IESNA Standard 90.1-2007
(Supersedes ANSI/ASHRAE/IESNA Standard 90.1-2004)
Includes ANSI/ASHRAE/IESNA Addenda listed in Appendix F

ASHRAE STANDARD

Energy Standard for Buildings Except Low-Rise Residential Buildings

I-P Edition

See Appendix F for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, the IESNA Board of Directors, and the American National Standards Institute.

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).

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ISSN 1041-2336

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- For steel-framed walls, ASHRAE 90.1-99 specifies a maximum effective conductivity of U-0.08 (R-13 effective)
- The value has dropped to U-0.064 (R-16) for ASHRAE 90.1-07
- To reduce effective U-value for ASHRAE 90.1-99 by 18% we require R-15 effective (U-0.066)
- Prescriptive requirements of nominal (rated) R-values for ASHRAE 90.1-07 is R-13 batt insulation + R-7.5 continuous insulation

Why Use Effective R-values?

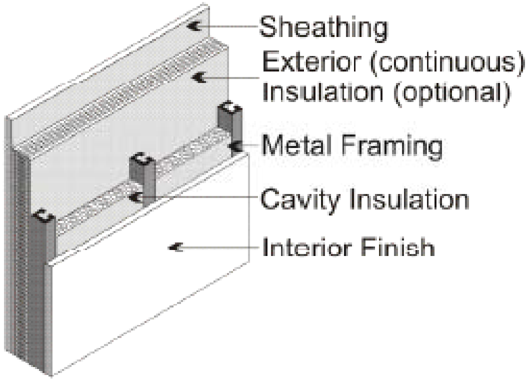
- Nominal R-values are the rated insulation values provided by the manufacturer
- Effective R-values are the actual thermal resistances provided by the insulation in a given assembly
- Effective R-values can be much less than the nominal R-value of the insulation due to thermal bridging
- Walls in our local industry are not typically designed as is specified by the minimum nominal R-values in ASHRAE 90.1

What Does ASHRAE 90.1 Assume?

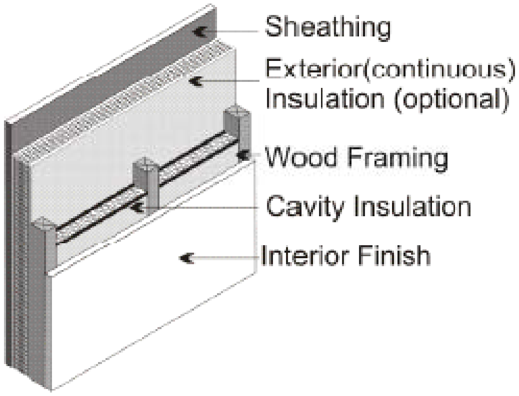
- Continuous insulation uninterrupted by framing

A graphic example of a pre-calculated assembly is shown below for each class. Compliance values for other assemblies are described in 90.1-2004 Appendix A, Table A3.3 for Steel Frame walls and Table A3.4 for Wood Frame walls. Graphic examples are shown in the User's Manual, Table B-5.

Steel Framed



Wood Framed and Other



What Does ASHRAE 90.1 Assume?

- Testing, calculation, or two- or three-dimensional modeling

Construction		Determination Method				
		Testing	Parallel Zone	Two Dimensional	Modified zone	Isothermal planes
Roof	Insulation entirely above deck	X				
	Metal building roof	X	X			
	Attic roofs, wood joist	X	X			
	Attic roofs, steel joist	X	X			
	Attic roofs, concrete joist	X	X			
Above-grade wall	Mass	X		X	X	
	Metal	X				
	Steel-framed	X	X		X	
	Wood-framed	X	X			
Floor	Mass	X	X			X
	Steel joist	X			X	
	Wood joist	X	X			X

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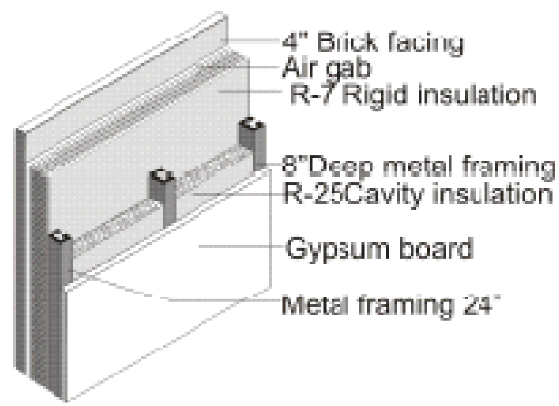
U-Factor Calculation Steel Framed Wall-Effective R Value Method

Layer	R-value	Source of Data
Exterior air film	0.17	Standard 90.1-2007 (§ A9.4.1)
4 in face brick	0.25	ASHRAE handbook
0.75 in air space	0.90	Standard 90.1-2007 (Table A9.4A)
Rigid insulation	7.00	Manufacturers data
0.625 in GWB	0.56	Standard 90.1-2007 (Table A9.4D)
Framing/cavity	9.60	Standard 90.1-2007 (Table A9.4B)
0.625 in GWB	0.56	Standard 90.1-2007 (Table A9.4D)
Interior air film	0.68	Standard 90.1-2007 (§ A9.4.1)
Total	19.72	
U-factor	0.051	



Opaque Wall Examples

- “loss” in insulation value is due to thermal bridges: conductive elements which pass through the building thermal envelope
- use of elements such as steel stud framing, z-girts, or exposed concrete slabs can result in major thermal bridging effects

Opaque Wall Examples

Concrete Mass Wall Building type

- Note continuous rigid insulation
- Panel on left is window wall

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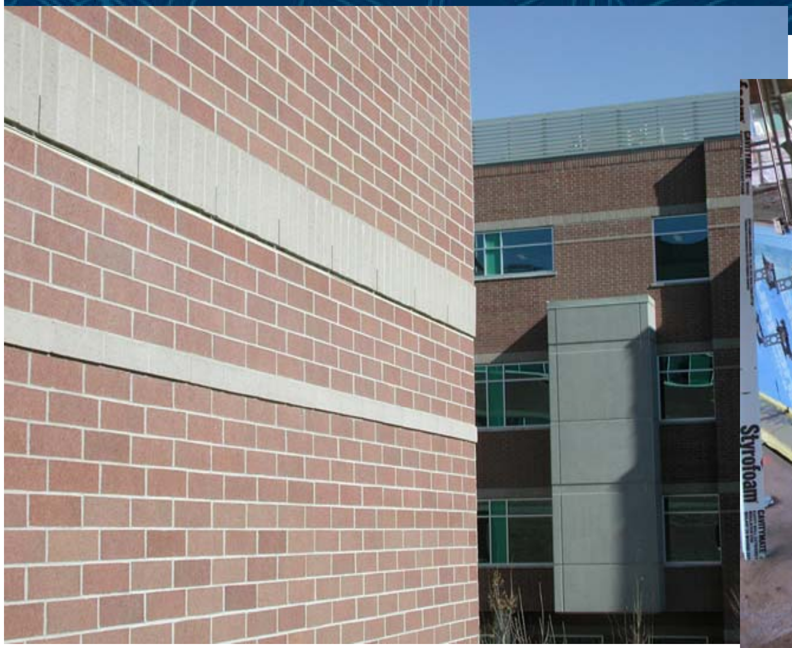
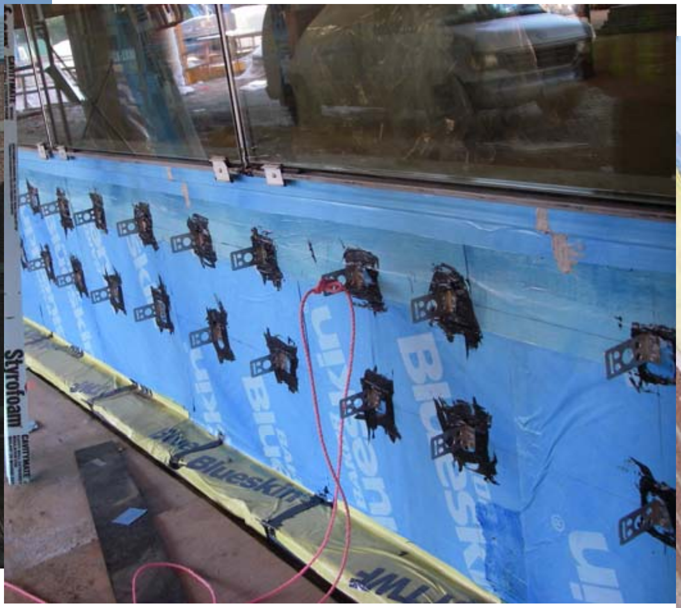
Opaque Wall Examples





Masonry Veneer Over Steel Stud

- Minimal exposed structure

Masonry Veneer Wall Ties

- Thermal bridge at shelf angle
- Minimum thermal bridge at ties

Opaque Wall Examples

Steel Stud & Metal Panel Wall

- More than 50% opaque wall

Cladding Girts Metal Panel Wall

- Can be horizontal or vertical
- Exterior insulation fits between girts creating thermal bridging

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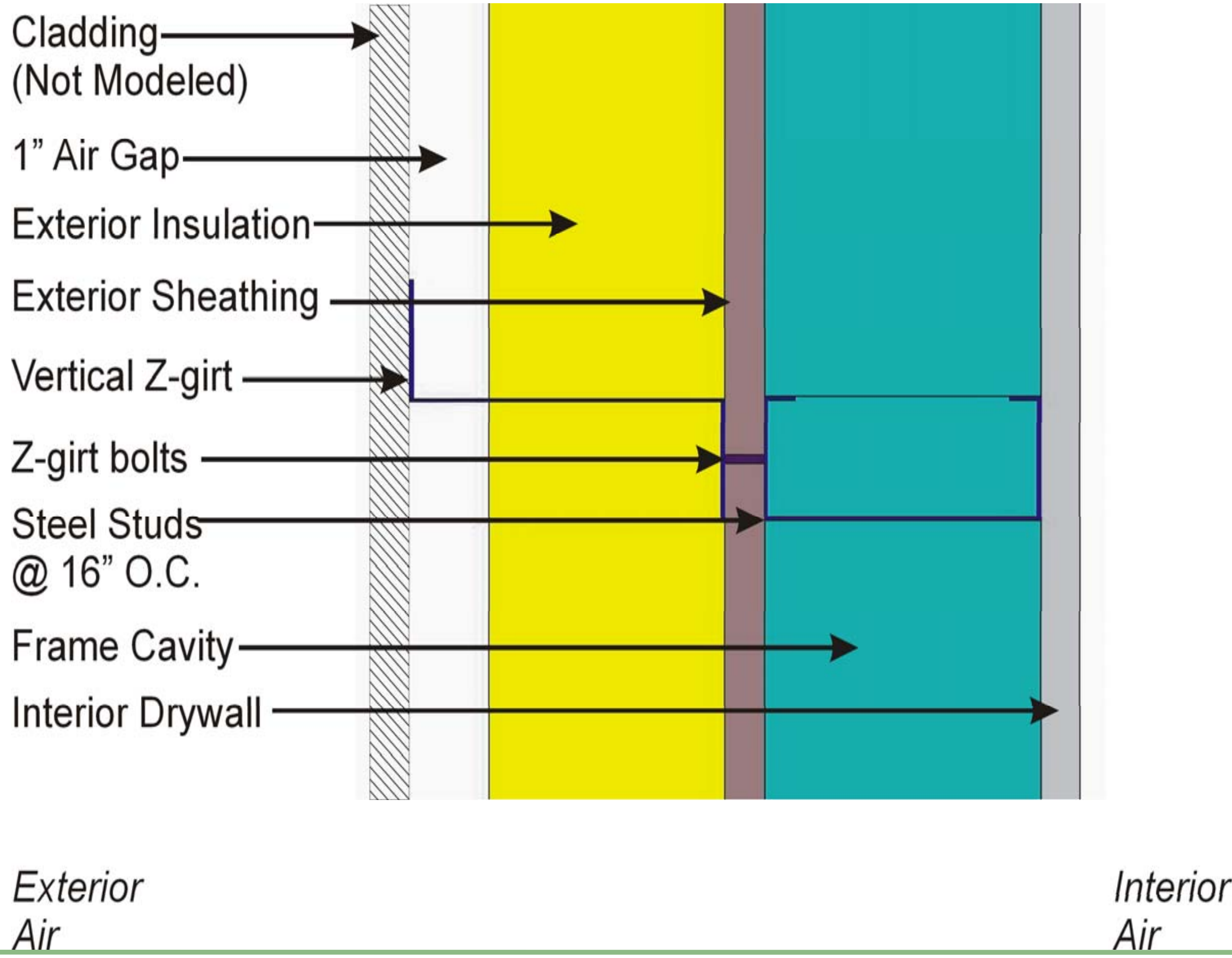
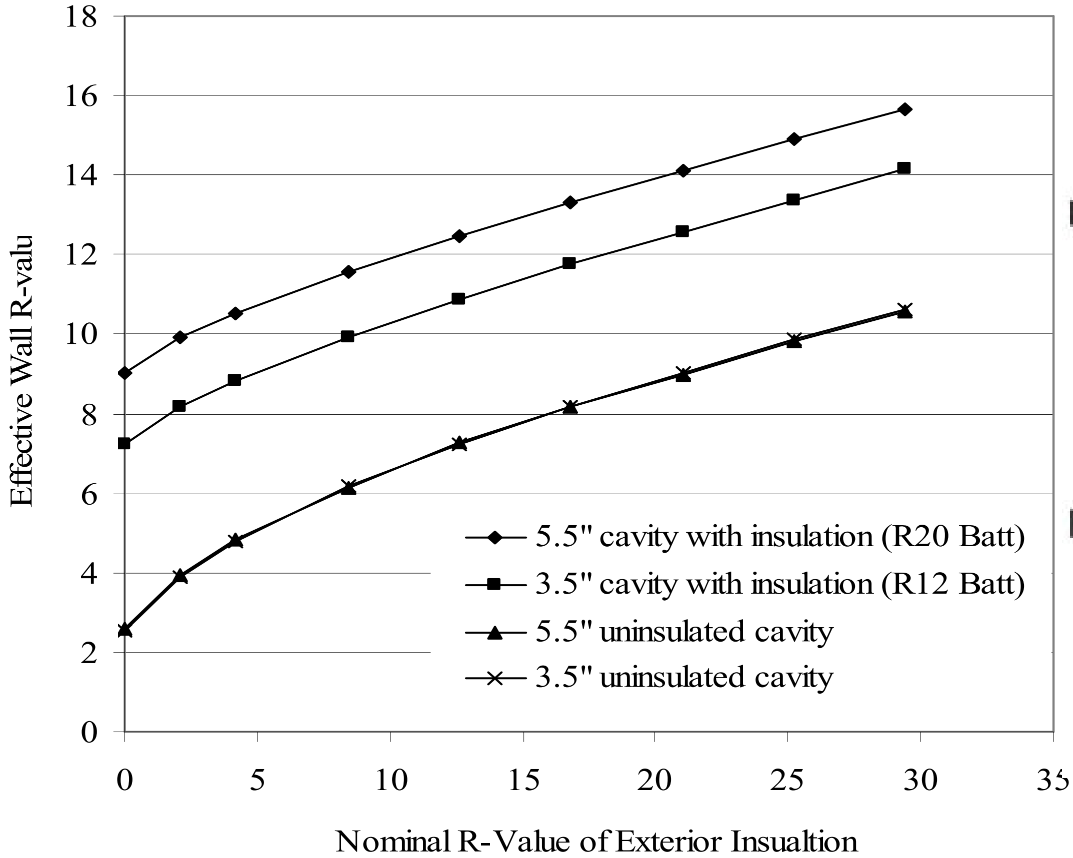
Thermal Bridging – 3D, 2D or 1D

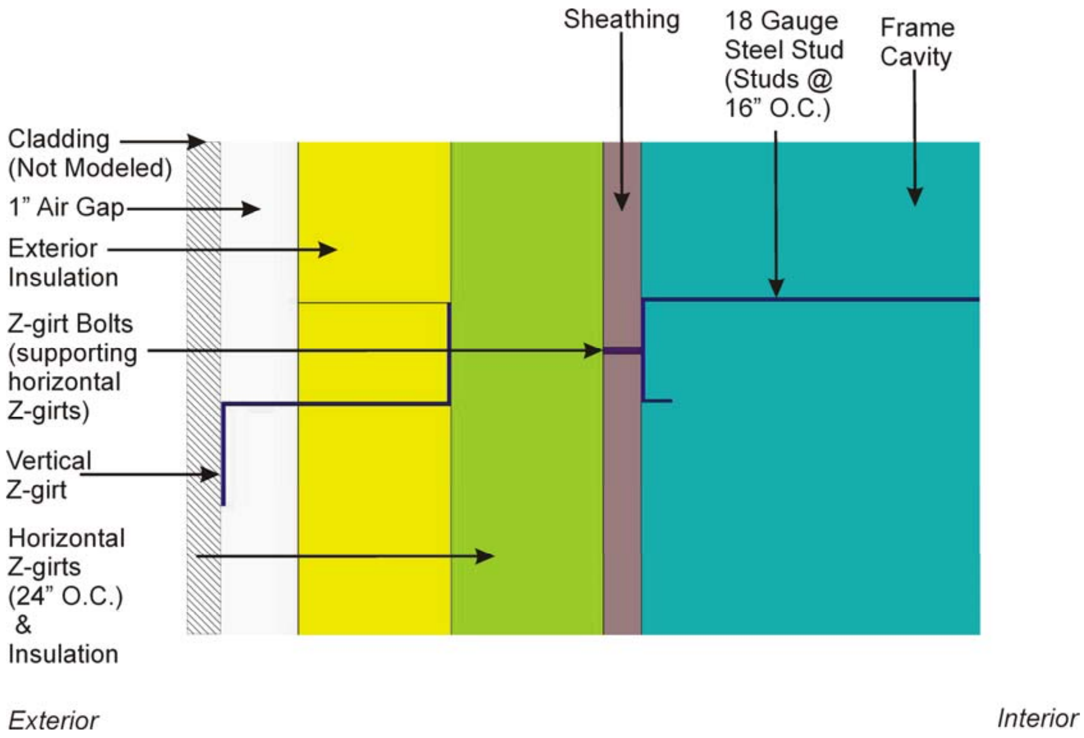


Effects of Thermal Bridging



- Thermal bridging affects both the stud space and the exterior insulation
- R20 Batt in 5 ½" cavity gives and effective R14
- Maximum effective R value levels off around R16

Assumptions



- Effective bolt connection
- Exterior cladding not directly modeled
- 2-D horizontal cross section
- Effective conductivity of horizontal z-girts
- Thermal mass ignored

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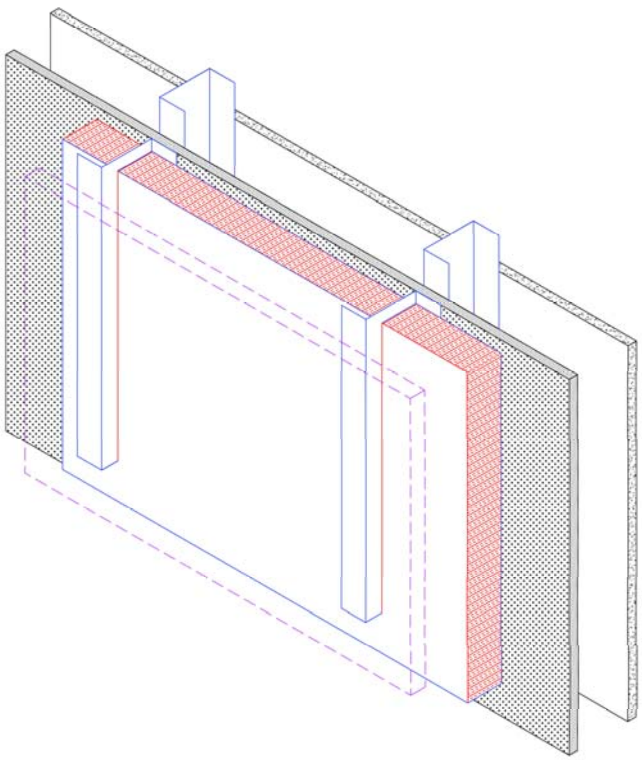
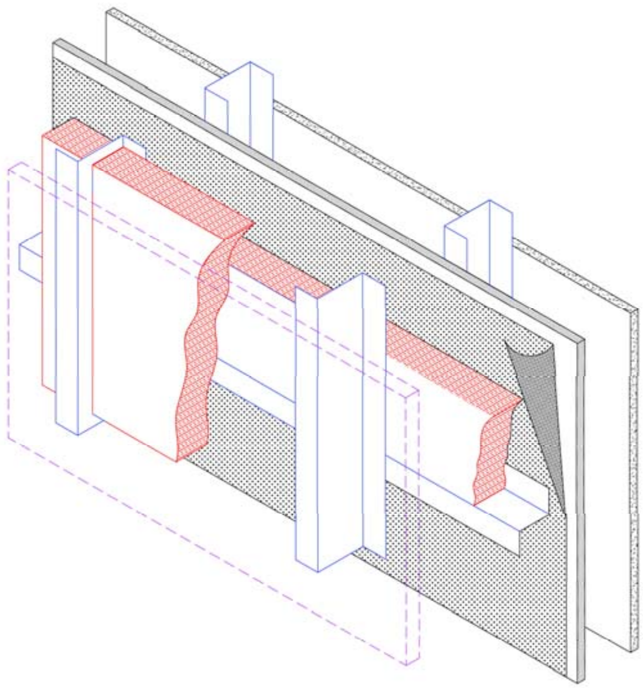
Effects of Thermal Bridging



Vertical Z-girts

- MH conducted thermal modeling to establish effective U-values for standard wall assemblies
- Modeling indicated that traditional cladding attachment methods, such as z-girts, greatly reduce insulation performance
- Nominal R-values of insulation are deceptive

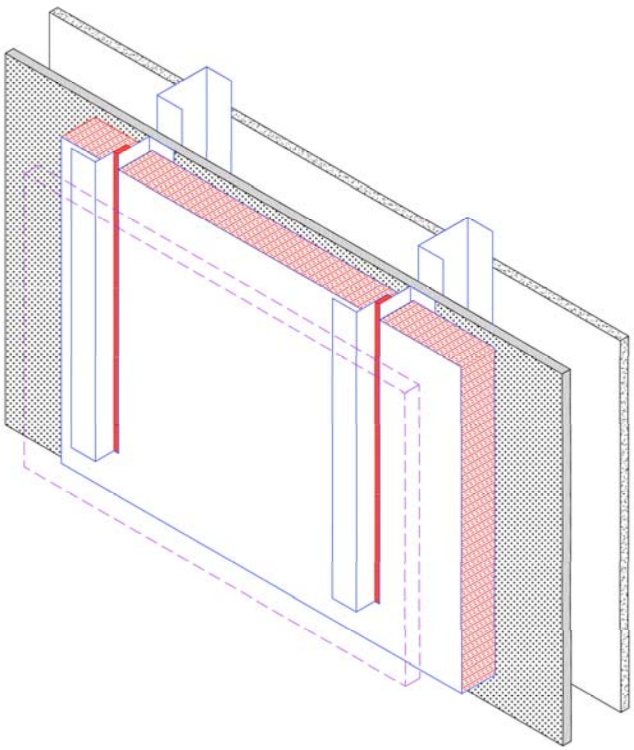
Layered Girts



Combined Horizontal and Vertical
Z-girts

- A layer of insulation and horizontal z-girts topped by a layer of insulation and vertical z-girts
- Roughly 60% improvement over regular z-girts

Thermally Broken Girts



Thermally Broken Vertical
Z-girts

- MH also modeled “alternative” cladding supports, designed to reduce thermal bridging and thus improve wall U-values
- Thermally broken z-girts
- Roughly 45% improvement over regular z-girts

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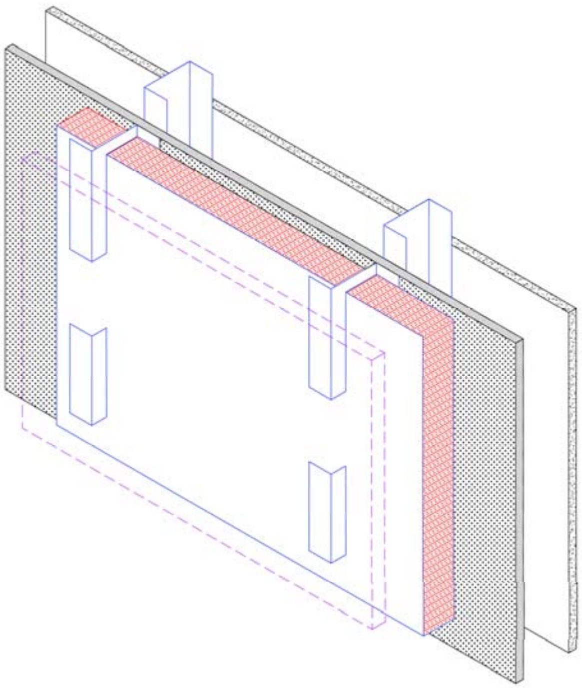
Intermittent Girts



Intermittent Vertical Z-girts

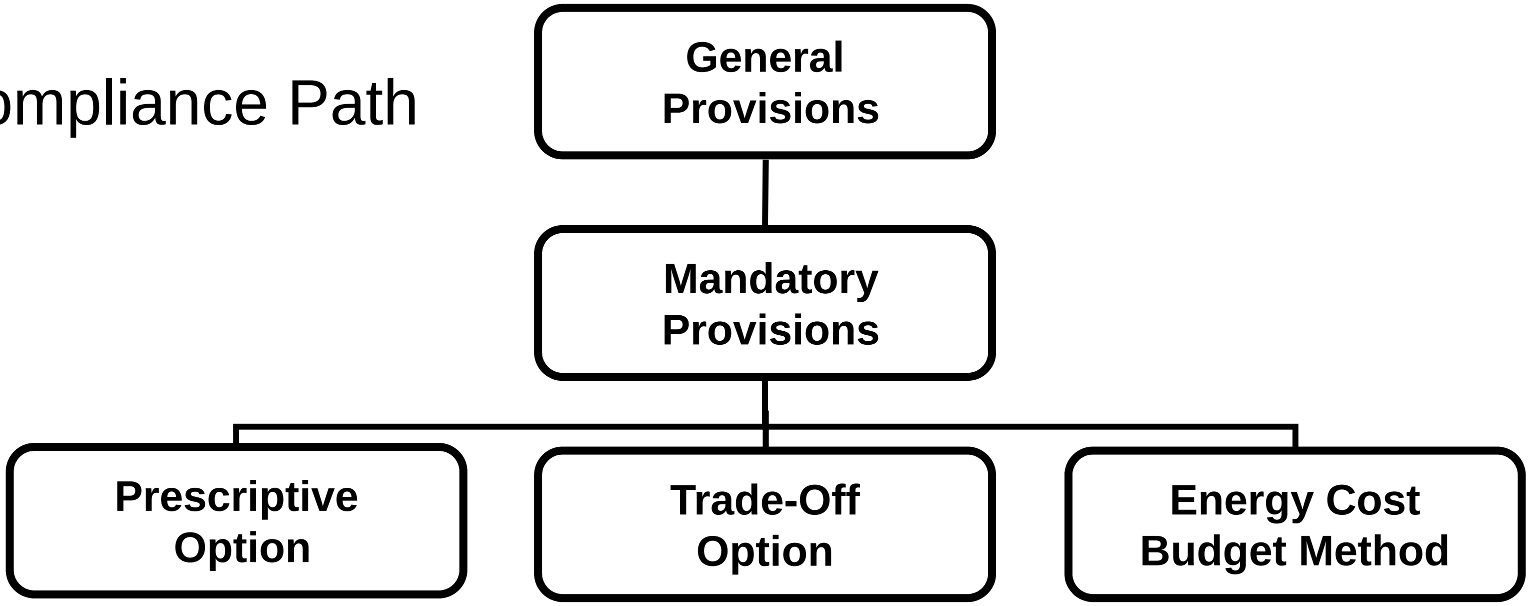
- A layer of insulation and horizontal z-girts topped by a layer of insulation and vertical z-girts
- Percent improvement depends on how much of the girt is left

Slab Edge Details

- Concrete frame with steel stud walls, exterior insulated walls with slab edge insulated.
- Secondary structure attachments

What about the Slab and Balconies?

- Compliance Path



- The goal in Appendix G (introduced in 2004) is to show that the *proposed building performance* is better than the *baseline building performance* by some given margin, the performance goal (intended for LEED)

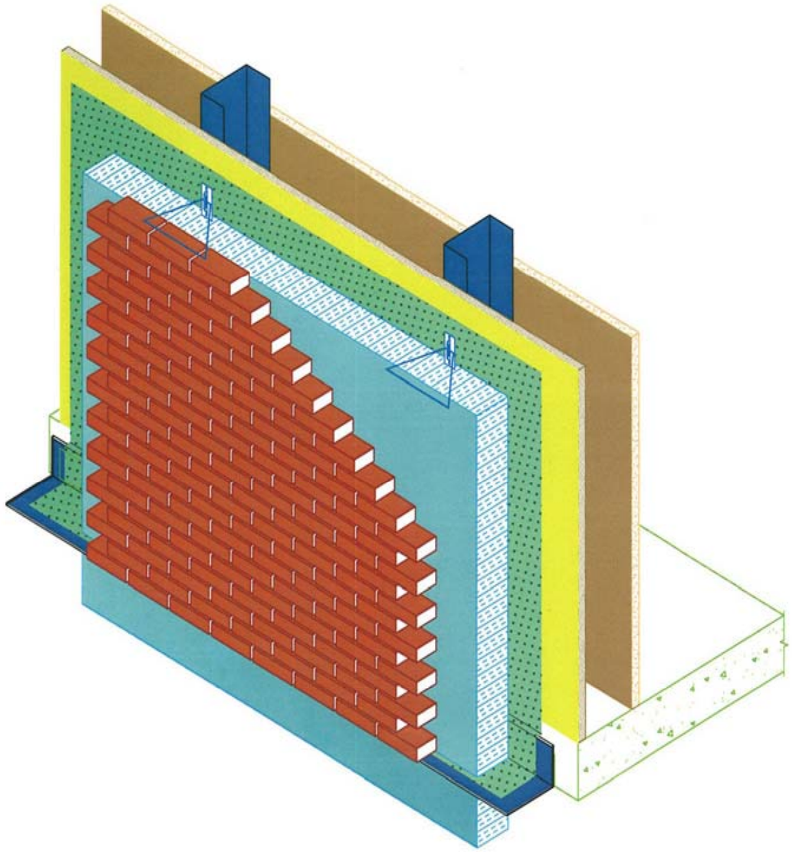
What about the Slab and Balconies?

- In Appendix G, for the proposed building performance, specifies that projecting balconies, perimeter edges of intermediate floor slabs, concrete floor beams over parking garages, roof parapet shall be modeled separately by

1. Separate model within the energy simulation model

2. Separate calculation of the U-factor and averaged with opaque adjacent surfaces. This average U-factor is modeled within the energy simulation model.

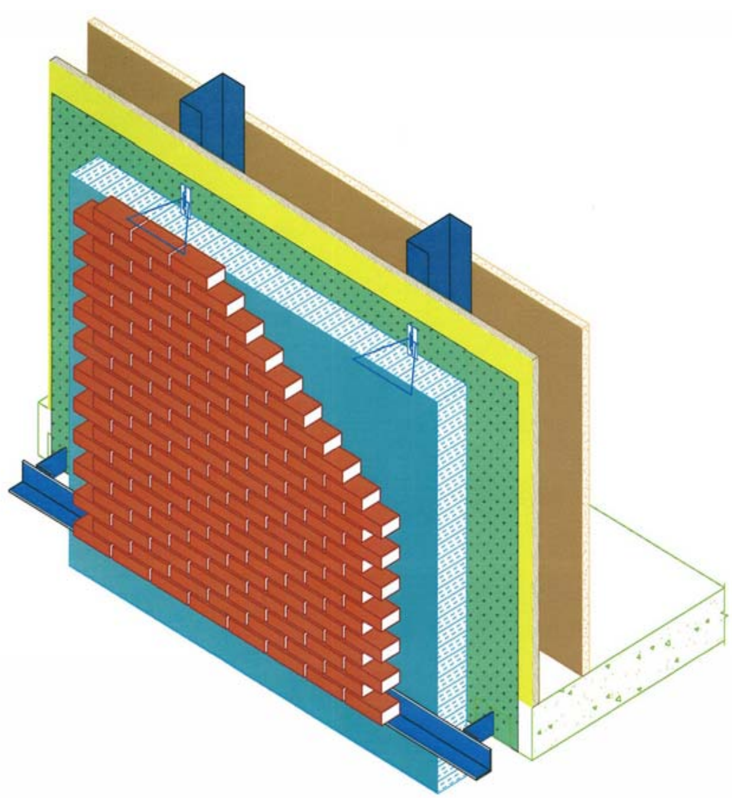
Slab Edge Details



Shelf Angle and Brick Ties

- MH also performed modeling to determine the impact of slab edge detailing on effective wall U-values
- Shelf angles or exposed concrete slabs provide a thermal bridge through the exterior plane of insulation

Slab Edge Details



Shelf Angle Mounted on Brackets

- Mounting shelf angle on brackets substantially reduces thermal bridging
- Other slab edge modeling included:
  - fully exposed slabs (i.e. balconies, eyebrows)
  - insulation and z-girts outboard of slab edge

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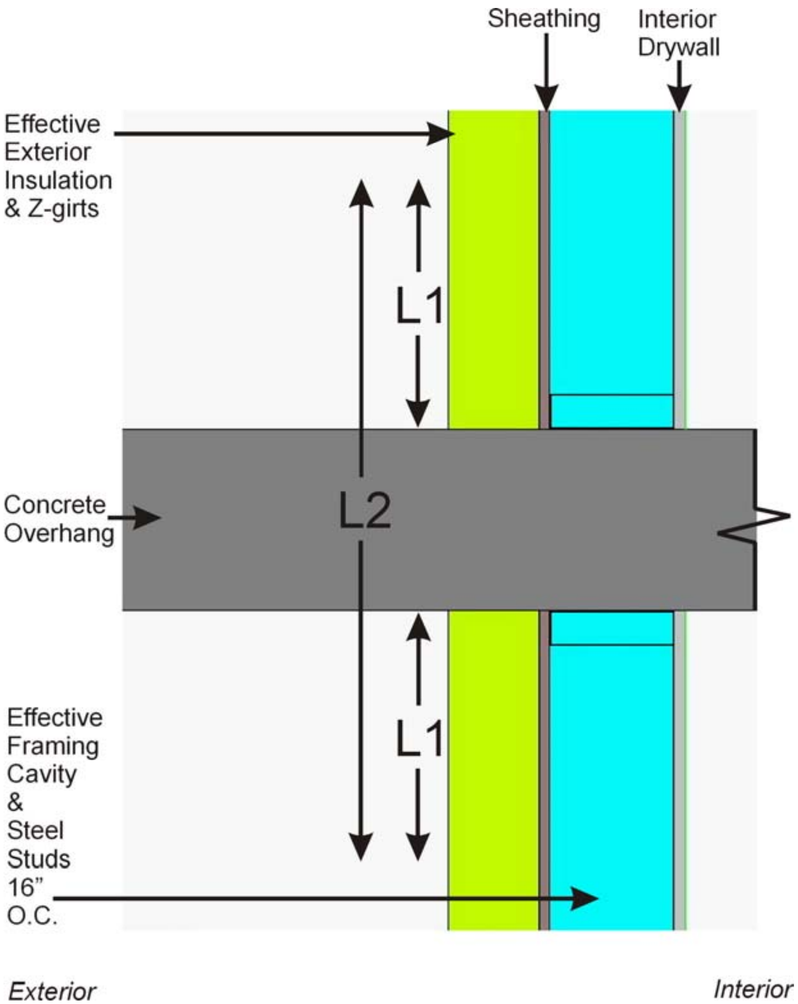
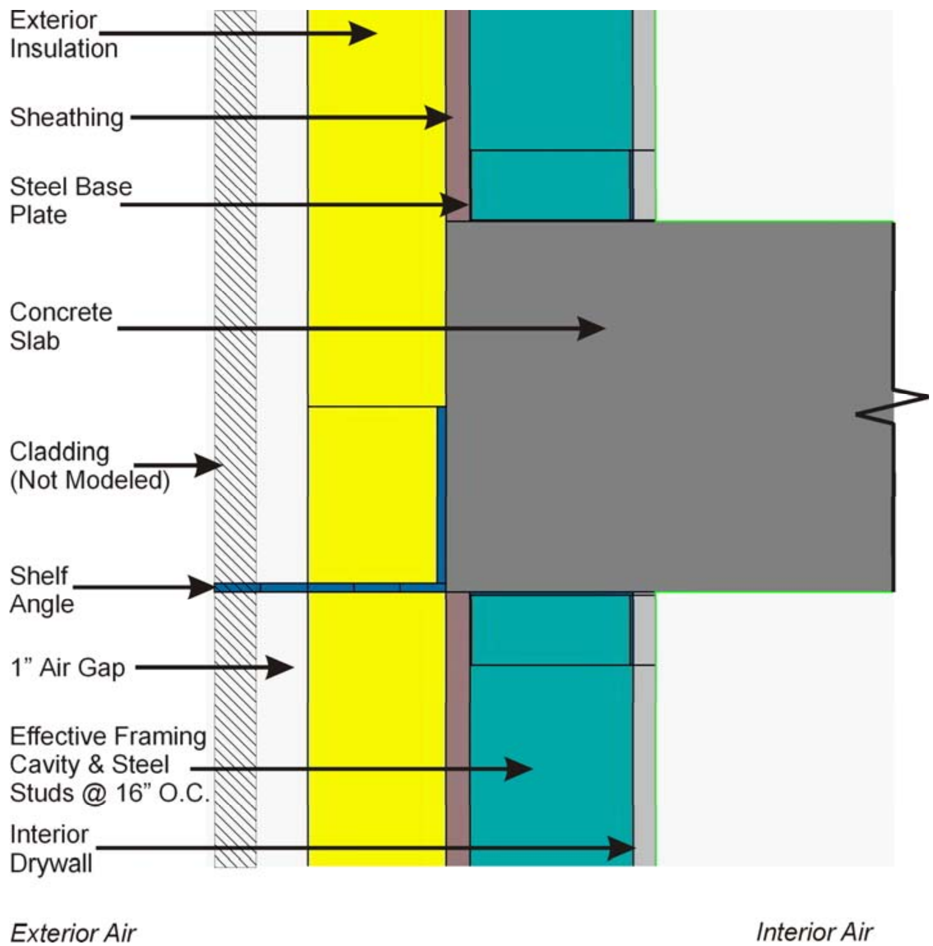
Slab Edge Details





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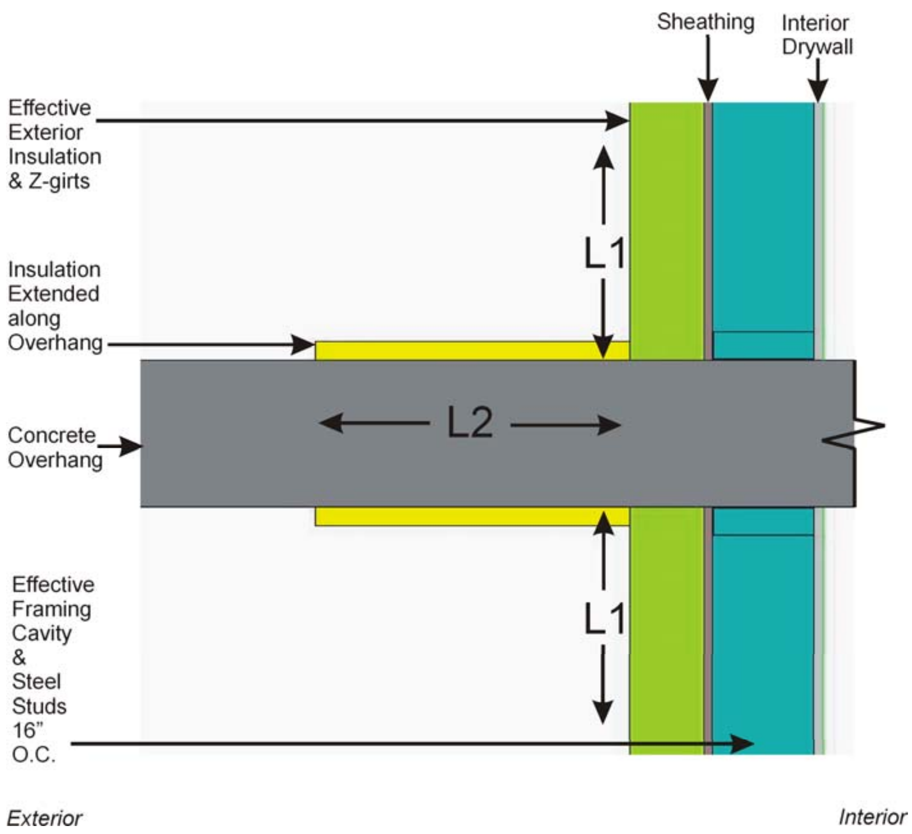
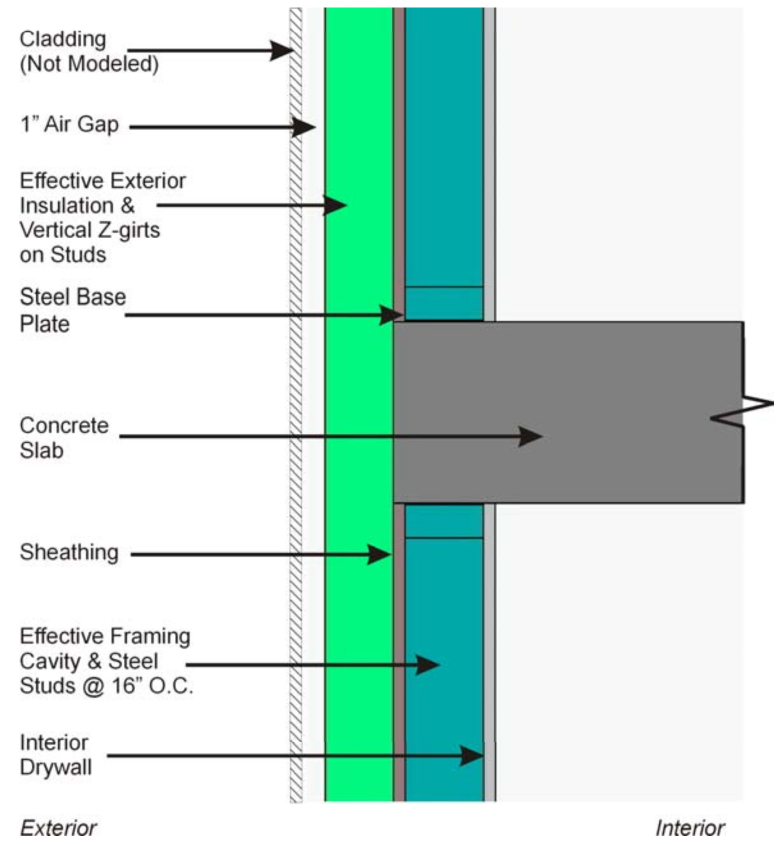
Slab Edge Details





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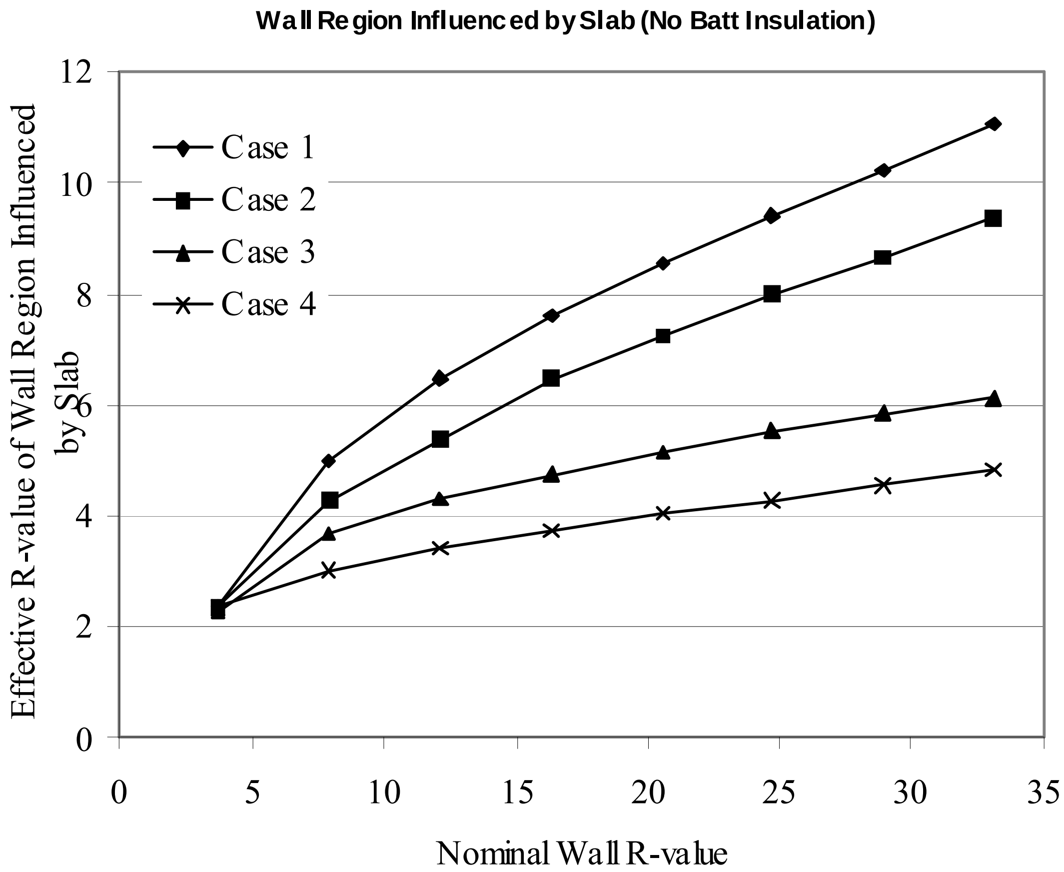
Slab Edge Details



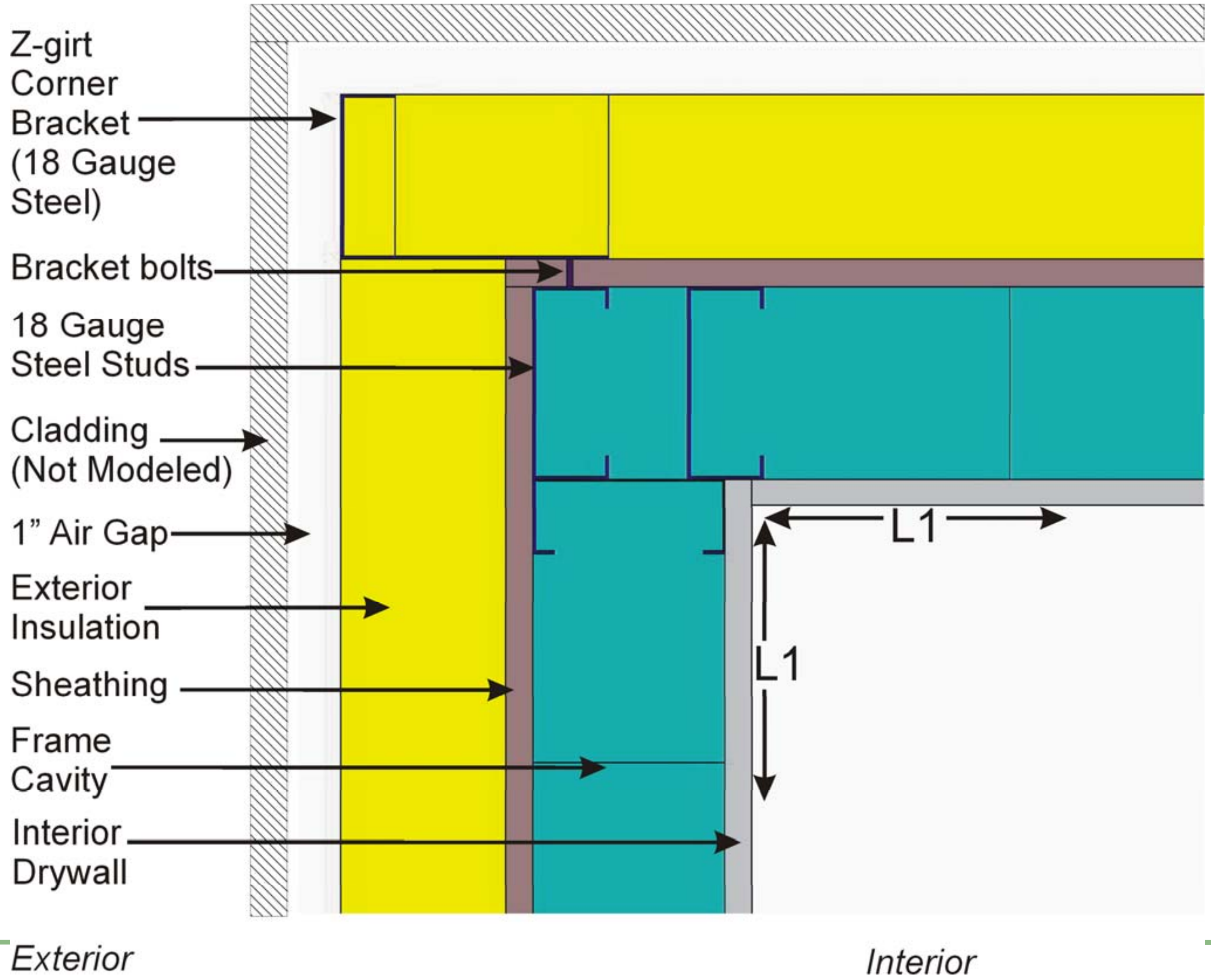
Case 1:
Insulation Outboard of Slab (Supported by Vertical Z-girts)

Case 2: 3” by ¼” Slab Mounted Steel Supports, 24” o.c.

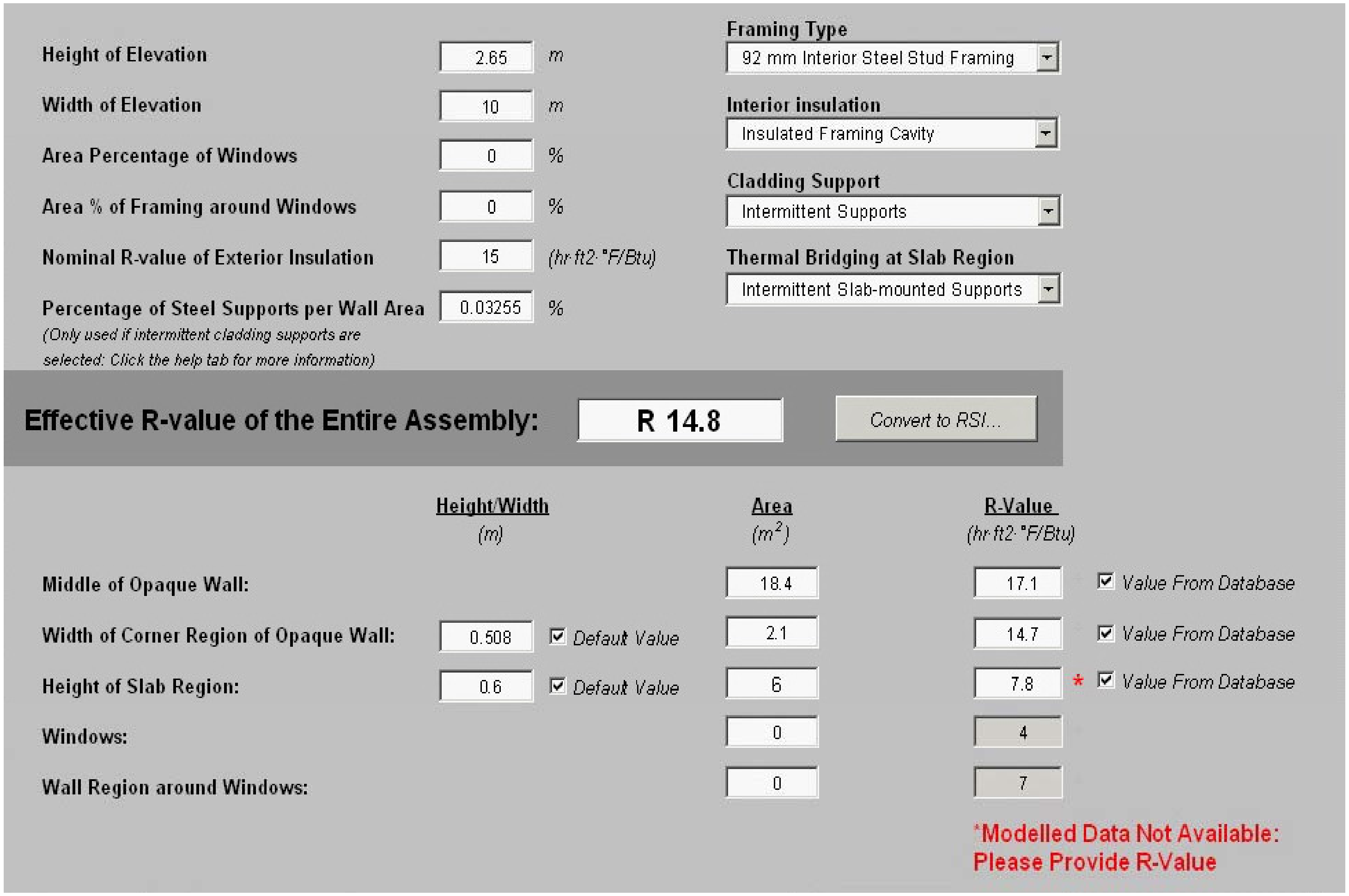
Case 3: ¼” Steel Shelf Angle

Case 4: Exposed Concrete Slab

Wall Corners



Effective R Value Tool



Program to compute the effective R-value of an elevation

Lookup Tables

Nominal Wall R-Value	Insulation Thickness (Inches)			Effective Wall R-Value for Various Cladding Attachments			
	Mineral Wool	EXPS	Spray foam	Vert. Girts	Hor. Girts	Broken Vertical Girts	Vert. & Hor. Girts
33.1	7.0	5.9	4.9	10.6			
28.9	6.0	5.0	4.2	9.8	13.5	14.6	16.8
24.7	5.0	4.2	3.5	9.0	12.3	13.4	15.0
20.5	4.0	3.4	2.8	8.2	11.0	12.1	13.2
16.3	3.0	2.5	2.1	7.3	9.5	10.5	11.3
12.1	2.0	1.7	1.4	6.1	7.7	8.6	8.8
7.9	1.0	0.8	0.7	4.8	5.6		
5.8	0.5	0.4	0.4	3.9	4.2		
3.7	0.0	0.0	0.0	2.6	2.6		

Summary of Effective Thermal Resistances for Exterior Insulated Walls (No Insulation in Frame Cavity, Slab Effects Ignored)

- MH developed a tabular method of presenting results
- Select the desired effective R-value, then look across the table to see the necessary insulation thickness for common insulation types and cladding systems
- Tables allow easy comparison of different wall systems when trying to meet a required effective R-value

Lookup Tables

Type of Thermal Bridging at Slab	Insulation Thickness (Inches)			Effective Wall R-Value			
	Mineral Wool	EXPS	Spray foam	Vert. Girts	Hor. Girts	Vert. & Hor. Girts	2″ x 1/16″ Brick Ties
Exposed Concrete Slab or Balcony	**7.0**	**5.9**	**4.9**	**7.8**	**9.9**	**11.1**	**12.1**
	6.0	**5.0**	**4.2**	**7.4**	**9.4**	**10.3**	**11.2**
	5.0	**4.2**	**3.5**	**6.9**	**8.7**	**9.4**	**10.2**
	4.0	**3.4**	**2.8**	**6.3**	**7.9**	**8.5**	**9**
	3.0	**2.5**	**2.1**	**5.7**	**7**	**7.6**	**7.8**
	2.0	**1.7**	**1.4**	**5.1**	**6**	**6.4**	**6.4**
	1.0	**0.8**	**0.7**	**4.2**	**4.7**		**4.8**
	0.5	**0.4**	**0.4**	**3.4**	**3.8**		**3.8**
	0.0	**0.0**	**0.0**	**2.6**	**2.6**		**2.6**
Exterior Insulation Placed Outboard of Slab	**7.0**	**5.9**	**4.9**	**10.6**	**13.4**		
	6.0	**5.0**	**4.2**	**10**	**12.6**		
	5.0	**4.2**	**3.5**	**9.1**	**11.5**		
	4.0	**3.4**	**2.8**	**8.2**	**10.3**		
	3.0	**2.5**	**2.1**	**7.3**	**9**		
	2.0	**1.7**	**1.4**	**6.3**	**7.5**		
	1.0	**0.8**	**0.7**	**4.8**	**5.4**		
	0.5	**0.4**	**0.4**	**3.8**	**4.2**		
	0.0	**0.0**	**0.0**	**2.6**	**2.6**		

Type of Thermal Bridging at Slab	Insulation Thickness (Inches)			Effective Wall R-Value	
	Mineral Wool	EXPS	Spray foam	2″ x 1/16″ Brick Ties	
				Shelf Angle bolted to slab	Shelf Angle fastened to 3”x ¼” steel brackets spaced at 24” o.c.
¼” Shelf Angle	**7.0**	**5.9**	**4.9**	**13.8**	**16.8**
	6.0	**5.0**	**4.2**	**12.8**	**15.2**
	5.0	**4.2**	**3.5**	**11.5**	**13.5**
	4.0	**3.4**	**2.8**	**10.1**	**11.6**
	3.0	**2.5**	**2.1**	**8.7**	**9.7**
	2.0	**1.7**	**1.4**	**7.1**	**7.7**
	1.0	**0.8**	**0.7**	**5.1**	**5.3**
	0.5	**0.4**	**0.4**	**4**	**4.1**
	0.0	**0.0**	**0.0**	**2.6**	**2.6**

3D Transient Heat Transfer

- Calculation methods and 2D steady state heat transfer software require many assumptions to estimate the thermal performance of complex 3D building envelope details
- Uncertainty can lead to over-design of HVAC systems, building operation inefficiencies, inadequate condensation resistance at intersection components and compromised occupant comfort
- ASHRAE RP 1145 established criteria for thermal analysis of 3D composite details using calibrated 3D transient heat transfer models

ASHRAE RP 1145

- Utilized a “equivalent wall model” to represent the dynamic response of complex assemblies by a fictitious one-dimensional wall
- The dynamic response of the fictitious wall is the same as a complex assembly of equivalent thickness (same resistance and thermal capacitance)
- Calibrated the computer model using dynamic hot-box testing (steady state, thermal ramp, stabilizing stage)
- Heat transfer modeling was completed for 20 common building envelope details (15 wood and steel stud systems and 5 insulated concrete forms)

ASHRAE RP 1365

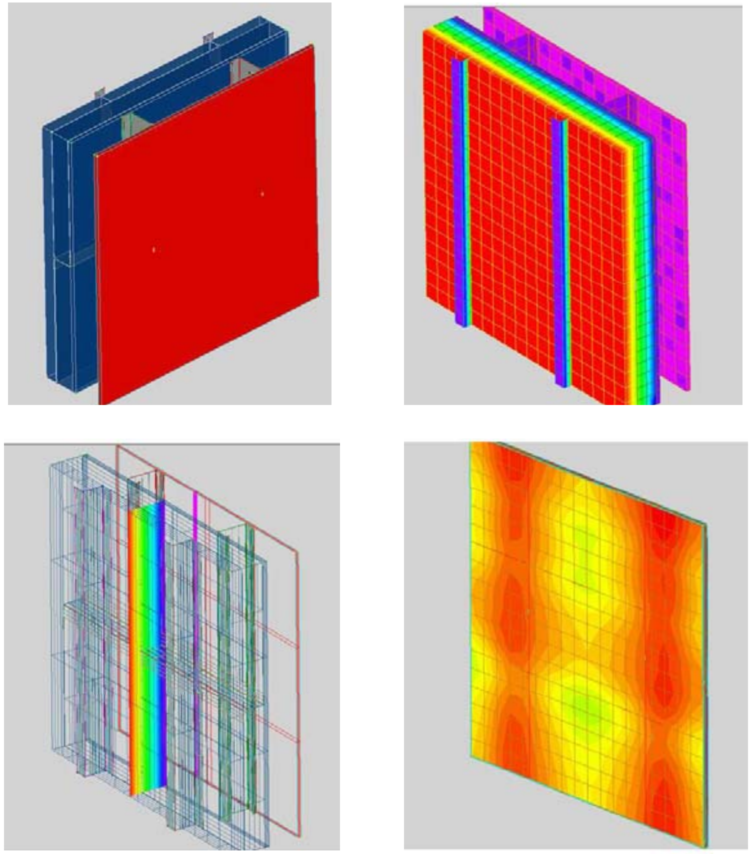
- Develop a catalogue of thermal performance values for building envelope details for mid- and high-rise buildings using time-transient dynamic 3D heat transfer software
- Goal is to provide procedures and a catalogue that will allow designers quick and straightforward access to information but with sufficient complexity and accuracy to reduce uncertainty in the thermal performance of building envelope components
- U-values and surface temperatures

ASHRAE RP 1365

- Envelope details will be selected that:
  - are relevant to ASHRAE 90.1, non-combustible buildings
  - are relevant to existing and future building stock and capture both retrofit and new construction details
  - Represent both high thermal performance envelopes and standard building practice
  - Include typical interior finishes and cladding systems and attachment methods for specific construction types

ASHRAE RP 1365

- Time-transient dynamic 3D heat transfer model that is capable of accurately modeling:
  - complex geometries
  - radiation through air spaces
  - radiation to the interior and exterior space
  - conduction of small areas of highly thermal conductive materials through larger areas of highly insulating materials
- Calibrate the model using existing lab testing



Thank You

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