Masonry & Energy Resources & Upcoming Code Provisions for Masonry Structures

Charles Clark, AIA, PE, LEED AP
Vice President, Engineering Services
Brick Industry Association

The Masonry Society

AIA Provider: 505119857

Course Description

This session will provide a state of the union on current research and resources available on masonry energy performance. An overview of recent research by the National Brick Research Center on thermal mass will be summarized along with efforts by the joint ACI/TMS Standard 122 Committee that are expected to lead to alternative code compliance provisions for masonry systems.

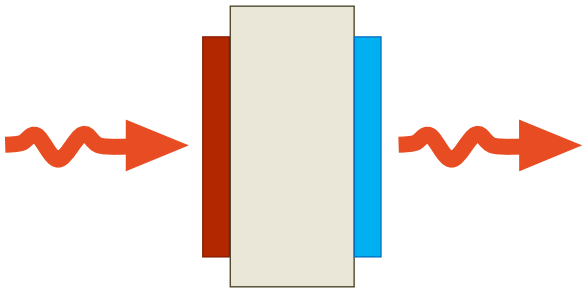
Learning Objectives

1. Understand the different methods used to describe heat transfer including R-value and thermal inertia
2. Compare the dynamic thermal performance of wall assemblies with anchored brick veneer to wall assemblies with other claddings based on the results of contemporary research
3. Understand the general structure and requirements of the proposed thermal mitigation standard for concrete, masonry and masonry veneer
4. Understand the general structure and requirements of the proposed thermal property standards for concrete, masonry and masonry veneer

3

Heat Transfer: R-Value

Heat transfer is complex…
so we simplify it…
…because we have to



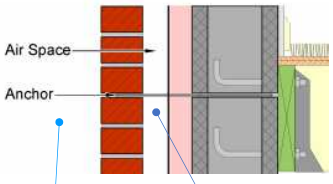
- ASTM C518 – *Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus*
- "Steady-state" means that the temperature on the hot plate does not change and stays constant

Heat Transfer: Thermal Mass

- Not accounted for in R-value!

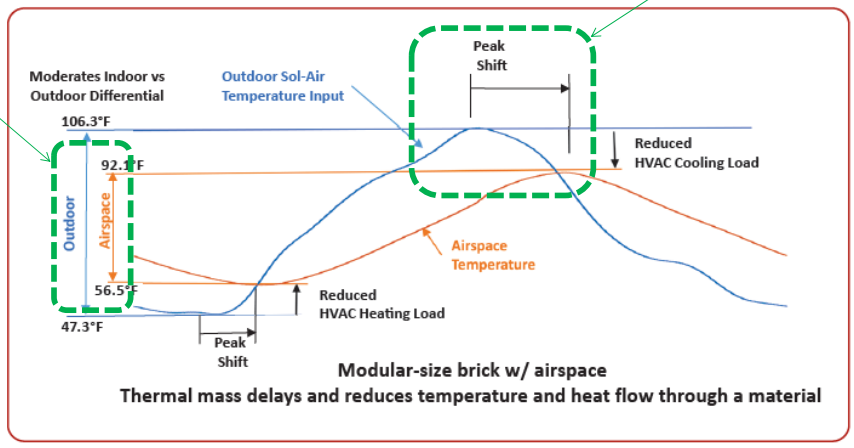
Shifts the impact of temperature extremes to off-peak hours = Lag Time

Reduces indoor temperature swing = better occupant comfort



Blue Line

Orange Line



Modular-size brick w/ airspace

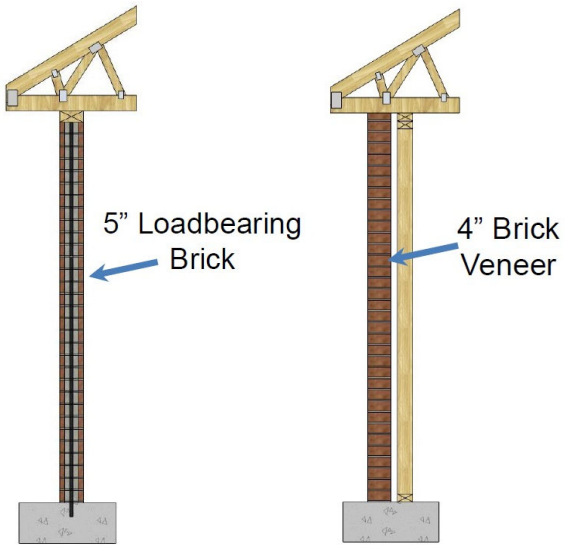
Thermal mass delays and reduces temperature and heat flow through a material

Mass Wall vs. Brick Veneer

- Mass wall – thermal mass counts
- Brick veneer – thermal mass does not count
- Similar amount of masonry, but different treatment by energy code...why?

- Energy Experts say:
  1. Lower heat capacity of wall
  2. Air space vented
  3. Brick ties act as thermal bridges

- Are these reasons valid?



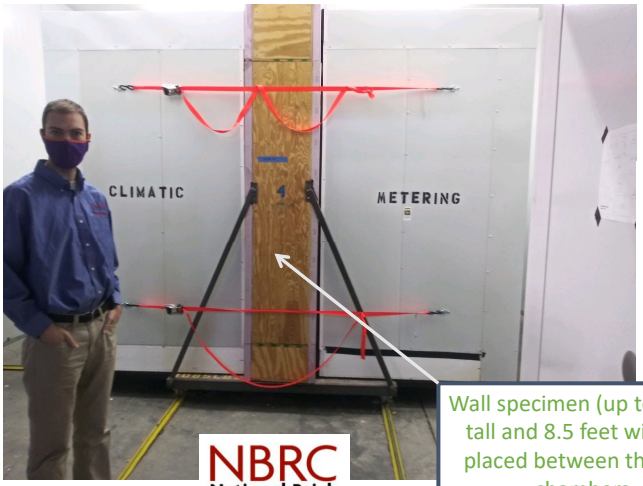
National Brick Research Center (NBRC) Hot Box Testing

Setup

Results

Debunking Energy Experts

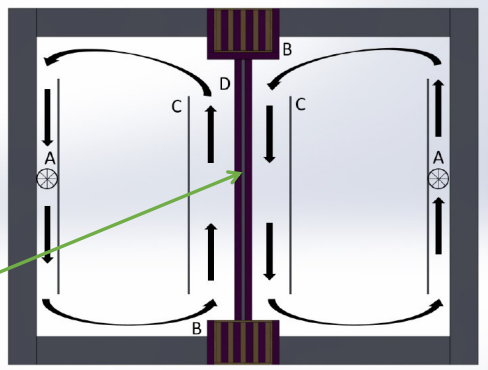
"Hot Box" Test Apparatus



Wall specimen (up to 6 feet tall and 8.5 feet wide) is placed between the two chambers

- NBRC modified the ASTM C1363 hot box with heat flux capacitors and thermocouples to measure dynamic thermal performance

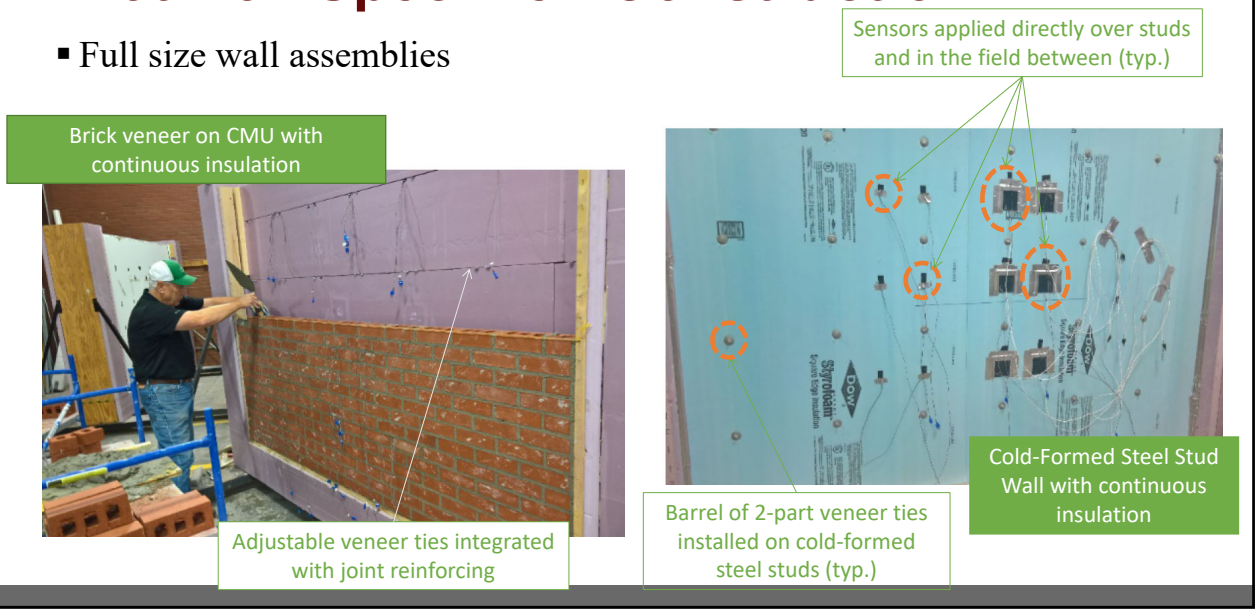
A. Fan
B. Frame
C. Baffle
D. Sample



Cross section through hotbox

Hot Box Specimen Construction

- Full size wall assemblies



Hot Box Test Specimens

- A variety of wall assemblies were tested in the hot box
  - Popular backings and cladding types, both with and without continuous insulation

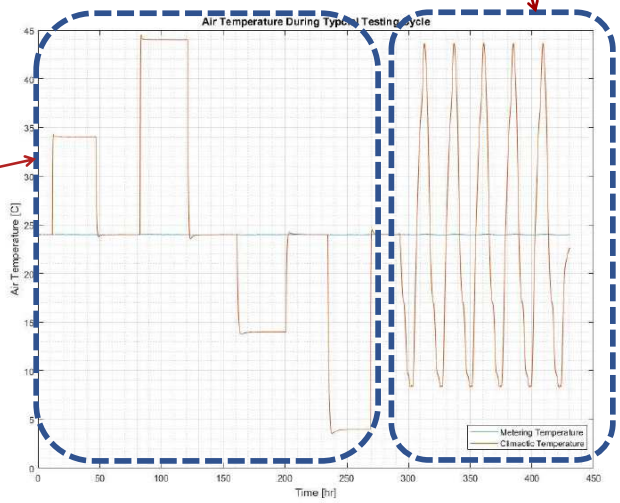
Cladding Type	Wood Backing	CMU Backing	Steel Stud Backing w/batt	Steel Stud Backing w/o batt
Brick Veneer	x	x	x	x
Brick Veneer w/ ci	--	x	x	x
EIFS – 1 inch	x	--	--	--
EIFS – 1.5 inch	x	--	--	--
EIFS – 2 inch	x	x	x	x
Vinyl/Fiber Cement	x	x	x	x
Vinyl/Fiber Cement w/ ci	--	x	x	x

Hot Box Temperatures

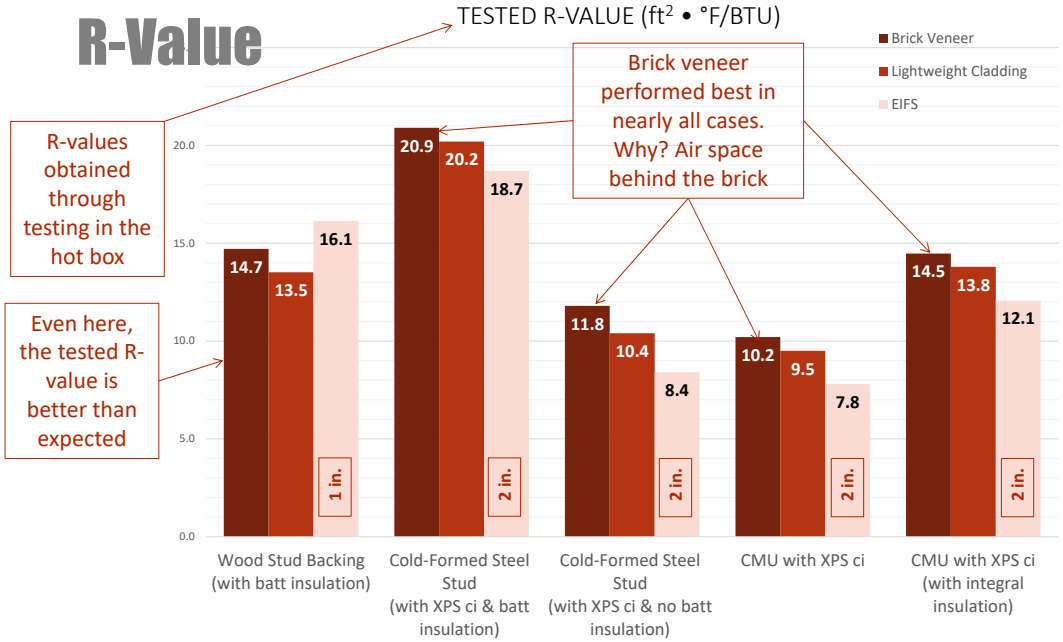
- Paired static temperature differences with a Sol-Air cycle
- Sol-Air Cycle
  - Created by National Bureau of Standards in 1973
  - 24 hours of air temperatures that represent daily temperature fluctuations

Sol-Air: Used to determine total amount of energy that reaches interior

Static: Used to determine thermal conductivity (U-factor & R-Value), heat capacity, and time to equilibrium



R-Value

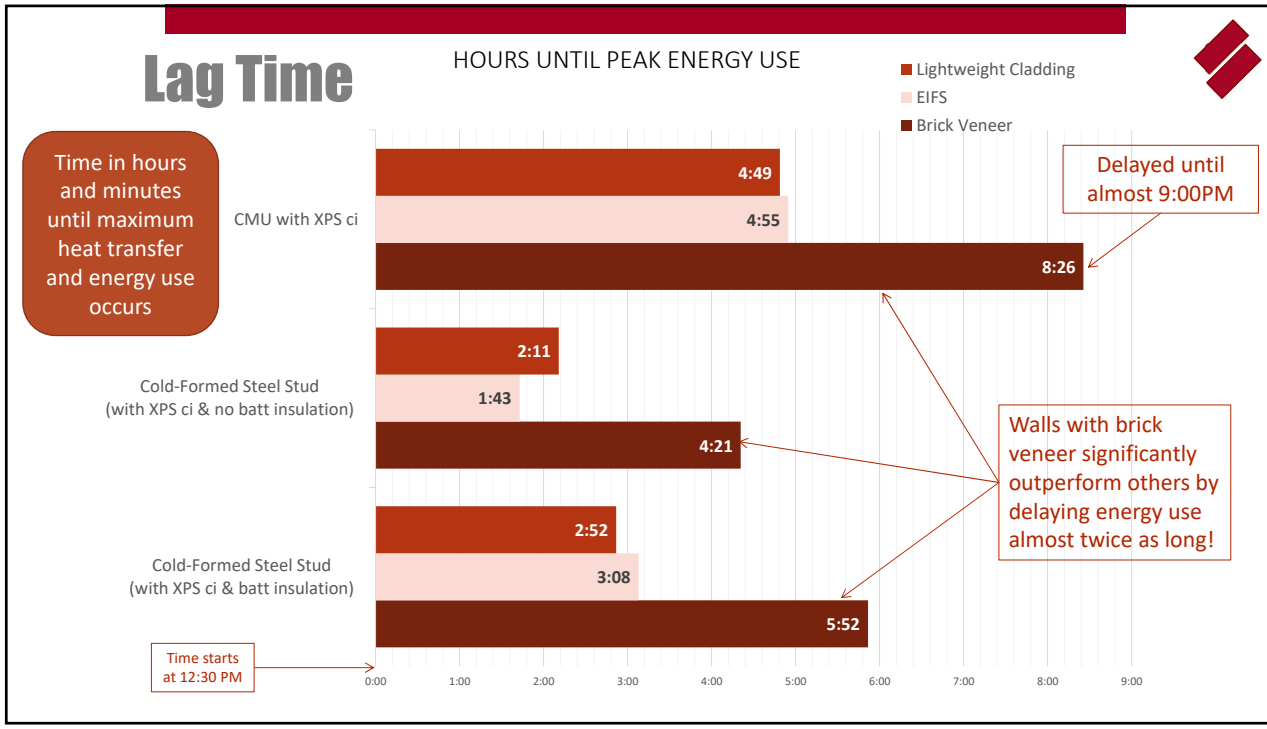


R-values obtained through testing in the hot box

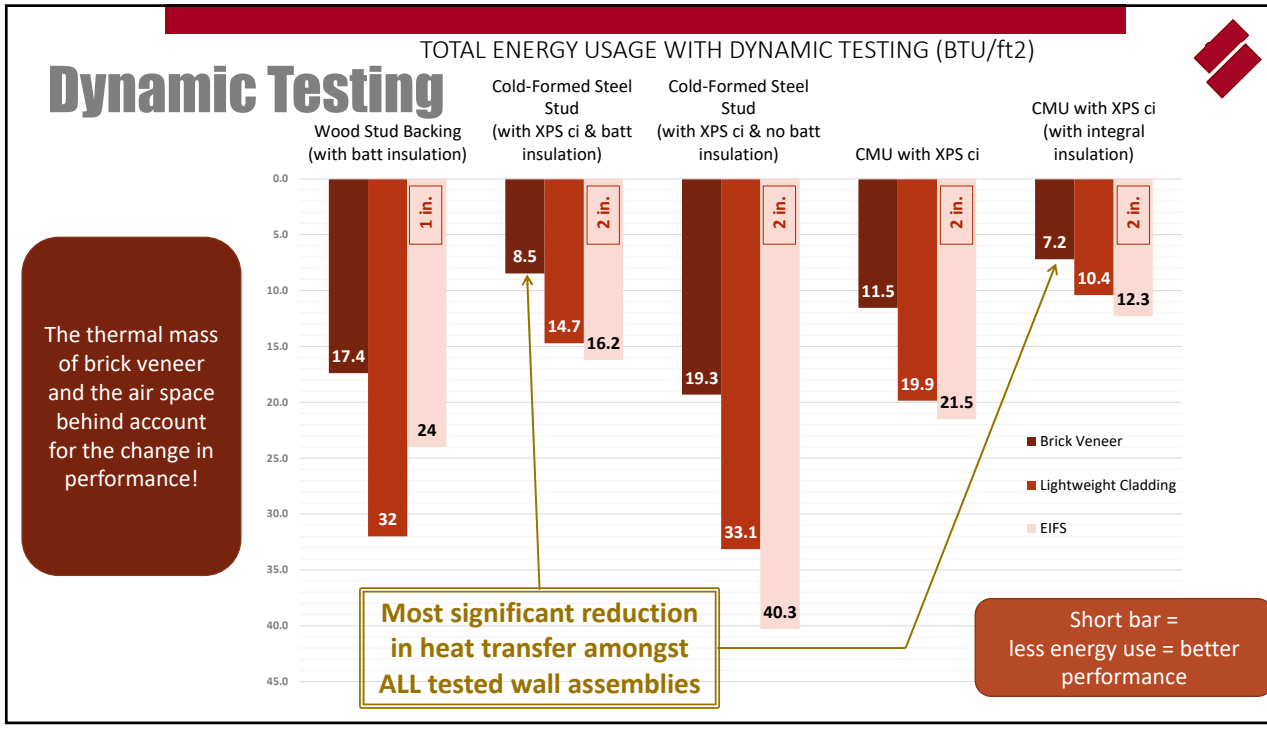
Even here, the tested R-value is better than expected

Brick veneer performed best in nearly all cases. Why? Air space behind the brick

Lag Time



Dynamic Testing



1. Heat Capacity of Wall - Apparent

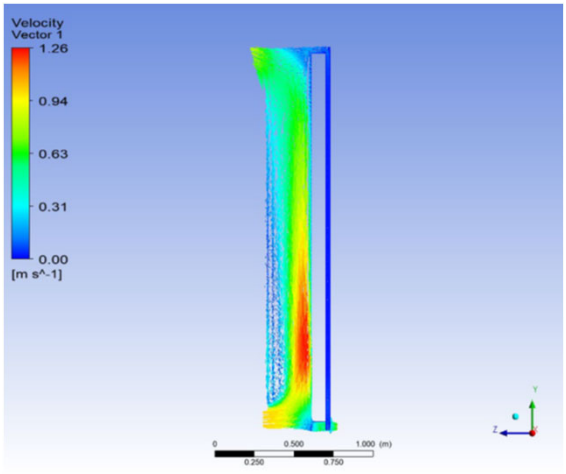
- Per testing, an apparent heat capacity can be determined
- Like mass walls, brick veneer walls have significant heat capacity compared to other assemblies

Wall System	Tested Heat Capacity (BTU/ft² * deg F)
Brick Veneer on Wood Framing	**9.95**
Brick Veneer on Cold-Formed Steel Framing (batt insulation only)	**14.6**
Brick Veneer on Cold-Formed Steel Framing (with ci and batt insulation)	**12.65**
Brick Veneer on Cold-Formed Steel Framing (with ci and no batt insulation)	**10.08**
Brick Veneer on Lightweight CMU (with ci)	**12.09**
EIFS on Cold-Formed Steel Framing (with batt)	1.83
EIFS on Cold-Formed Steel Framing (no batt)	0.87
Lightweight Cladding on Cold-Formed Steel Framing (with ci and batt insulation)	0.94
Lightweight Cladding on Cold-Formed Steel Framing (with ci and no batt insulation)	0.37
CMU with EIFS	2.32

2. Vented Air Space – Measured Behavior

- Air flow in cavity space
  - Fluid dynamics model simulated all forms of heat transfer across air space
    - Supermajority of heat transfer due to radiation (~80%)

Because radiation is so dominant, the behavior of the cavity behind brick does not match the code assumptions!



2. Vented Air Space - Measured Behavior

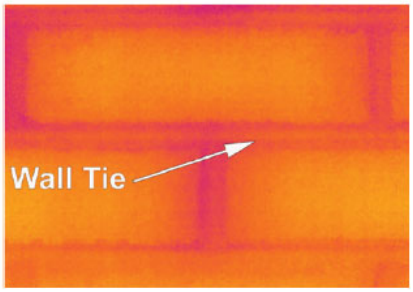
Property	Hot Box—Closed Weeps	Simulation—Closed Weeps	Hot Box—Open Weeps	Simulation—Open Weep—1 m/s
Whole Wall R-Value $[m^2 \cdot K/W]$ $(ft^2 \cdot °F \cdot hr/BTU)$	2.59 (14.7)	2.46 (14.0)	2.60 (14.8)	2.45 (13.9)
Stud Wall R-Value $[m^2 \cdot K/W]$ $(ft^2 \cdot °F \cdot hr/BTU)$	2.27 (12.9)	2.20 (12.5)	2.27 (12.9)	2.20 (12.5)
Brick + Air R-Value $[m^2 \cdot K/W]$ $(ft^2 \cdot °F \cdot hr/BTU)$	0.317 (1.8)	0.264 (1.5)	0.334 (1.9)	0.246 (1.4)

Negligible difference in R-value when weeps were open vs. closed

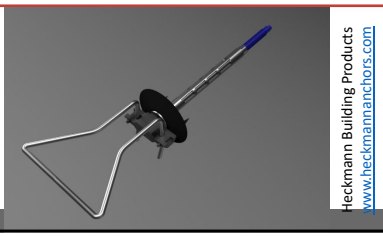
- Hot Box testing with open and closed weeps & Air flow modeling (CFD):
  - Cavity does not degrade R-value
  - Cavity does not negatively affect thermal performance

3. Are Ties Thermal Bridges?

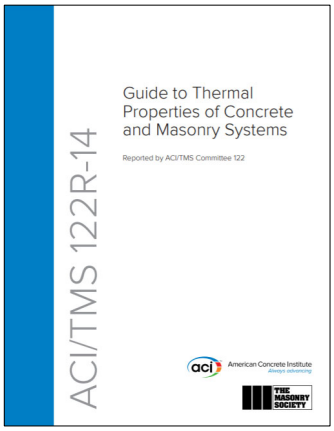
- It's a common misconception
- Brick ties are NOT thermal bridges
  - Small tie vs. large brick veneer
  - Slow heat transfer between materials
- To further limit thermal conductivity:
  - Use stainless steel ties
  - Use "thermal" ties to isolate metal parts



Veneer ties are not visible in infrared (IR) photos taken during hotbox testing, illustrating that ties are not thermal bridges.



ACI/TMS 122 Masonry Energy Standard



Three New Standards

1. Thermal Bridge Mitigation Standard
2. Thermal Property Standard for Non-Residential Buildings
3. Thermal Property Standard for Residential Buildings

Thermal Bridge Mitigation Standard

- Required for new buildings & additions in Climate Zones 5-8
- Requires compliance with one of the following:
  1. **Prescriptive Method**
  2. **Building Tradeoff Method**
  3. **Whole Building Simulation Model**
- Conditions not requiring analysis

  Uninsulated walls, Buildings with <20% fenestration, Masonry veneer ties, Small penetrations
- U-factors for assemblies

  2 or 3 dimensional method, Lab testing, Published value, ISO, Masonry-Isothermal planes method, Metal-Zone or Mod. Zone

Prescriptive Method

1. Building envelope walls extending above roof
   - Applies to Climate Zones 6-8
   - Extend insulation to top of roof insulation or underside of roof deck
   - Exception allows interruption of insulation for connections
2. Balconies and projections
   - Applies to Climate Zones 5-8
   - Total length of balconies and projections limited to percentage of floor perimeter
     - For floor area > 50% residential, limited to:

       30% in CZ 5; 20% in CZ 6;10% in CZ 7; 0% in CZ 8
     - For floor area < 50% residential, limited to: 10%
   - Exception where balconies and projections: Have min. R-3 insulation or thermal break; Are supported by point load connections; Are not extensions of floor slabs; Provide weather protection to pedestrians

Prescriptive Method

3. Shelf angles supporting masonry veneer
   - Applies to Climate Zones 6-8
   - Requires stand-off structural connections
   - Exceptions for
     - 25% of floor perimeter
     - Where thermal break is installed
4. Other thermal bridges

Building Envelope Tradeoff Method

- Tradeoff method must comply with applicable energy code or standard
- Only applies to components and assemblies that do not meet Prescriptive Method

Whole Building Simulation Model

- Model must comply with applicable energy code or standard
- Only applies to components and assemblies that do not meet Prescriptive Method

Thermal Property Standards For Non-Residential & Residential Buildings

- Required for new buildings & additions
  - Portions of buildings with walls of concrete, masonry, or masonry veneer
  - Portions of buildings with concrete floors above unconditioned space and slab-on-grade floor
- Requires compliance with one of the following:
  1. **Prescriptive Method**
  2. **Building Tradeoff Method**
  3. **Whole Building Simulation Model**

Prescriptive Method

Each concrete or masonry building envelope assembly shall comply with one of the following:

1. Add min. R-value insulation in Table in framing cavities and continuous insulation
2. Use assembly with U-factor, C-factor, or F-factor less than maximum in Table
3. Building envelope assemblies of semi-heated spaces must comply with ASHRAE 90.1

TABLE - Building Envelope Requirements

Type of Exterior Wall	Climate Zone 3	
	Assembly maximum	Insulation R-value, min.
Mass walls, above grade	U-0.123	R-7.6 ci
Masonry veneer [e], metal framed walls, above grade	U-0.089	R-13 + R-2.1 ci[a,c]
Masonry veneer [e], wood framed walls, above grade	U-0.100	R-8.0
Mass floors above unconditioned space	U-0.074	R-10 ci
Slab-on-grade floors, unheated	NR or F-0.730	NR
Slab-on-grade floors, heated	F-0.860	R-15 for 24 in.
Below grade walls	NR or C-1.140	NR

[a] The following abbreviations apply: ci = continuous insulation

[c] Where the surface adjacent to the air space and opposite the veneer is a reflective surface (reflective barrier) with an emissivity no greater than 0.05 when measured in accordance with ASTM C1371, the ci requirement is permitted to be reduced by R-1.6 ci. Where such a surface is installed and the ci requirement is R-1.6 ci or less, no ci shall be required.

[e] Masonry veneer shall have a minimum specified thickness of 2-5/8 in. (67 mm).

Building Envelope Tradeoff Method

- Tradeoff method must comply with applicable energy code or standard
- COMcheck or other similar

Whole Building Simulation Model

- Model must comply with applicable energy code or standard
- Only applies to components and assemblies that do not meet Prescriptive Method

Thermal Property Tables

This concludes The American Institute of Architects Continuing Education Systems Course

THE MASONRY SOCIETY

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Chip Clark AIA, PE, LEED AP
Email: cclark@bia.org
Phone: 703-674-1531