
NRMCA
Concrete Design for Energy Efficiency
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BUILD WITH STRENGTH

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Learning Objectives

- Define the terms and concepts of concrete building envelope
- Understand evolution of concrete and the energy code
- Identify the envelope requirements of energy codes
- Discuss how concrete envelopes serve as a primary solution to compliance with increased performance

Why Concrete Matters

- No building material has been asked to do more and delivered than concrete.
- Architects in every era since have used concrete to create structures that define their time — and then outlast it



Why Energy Efficiency Matters

- Saves fuel resources
- Lower CO2 emissions
- Move towards requiring the transition toward greater use of renewable energy in buildings
- Lower owner costs on utility bills
- Energy efficiency measures are cost-effective



Sustainability + Energy Efficiency



Embodied

- Local material
- Uses waste materials
  - Fly Ash (Coal)
  - Slag (Steel)
  - Biochar (Wood

Operational

- Thermal mass
  - Reduced energy demands
- Resilient / Durable
  - Reduced maintenance
  - Increased longevity

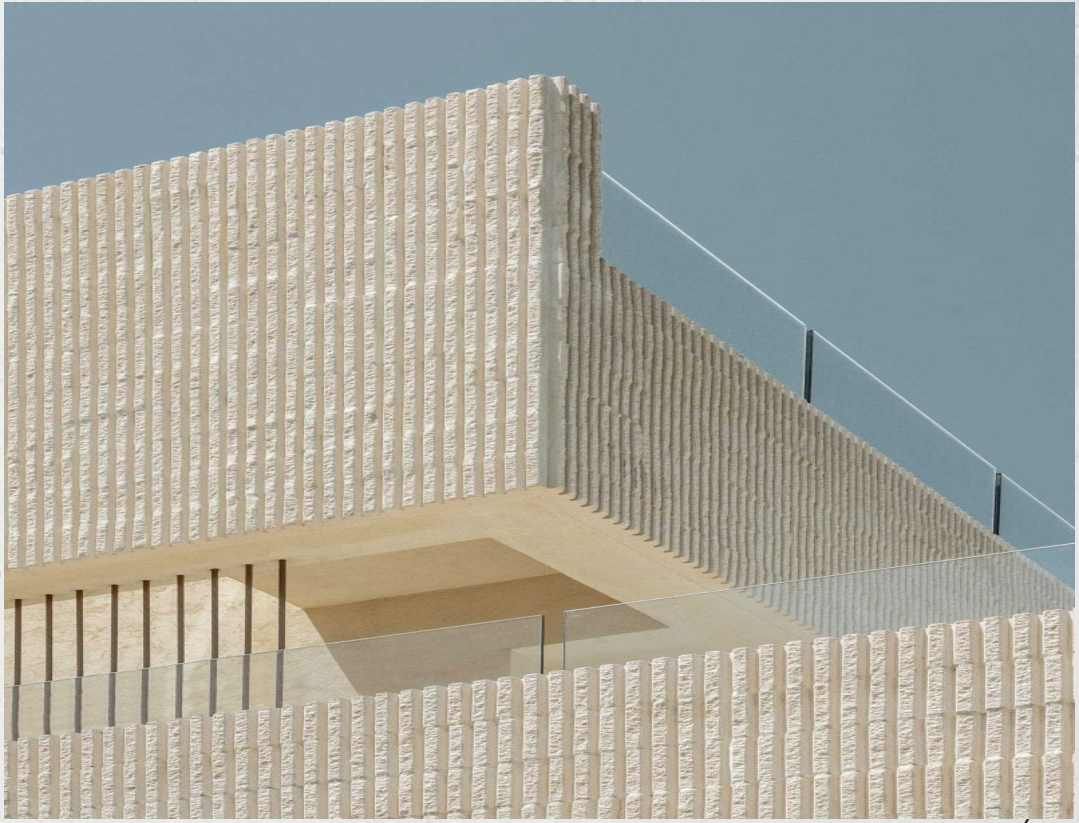
End-of-Life

- Carbon uptake
  - Absorbs CO_2
- Recyclable

Resilience + Energy Efficiency

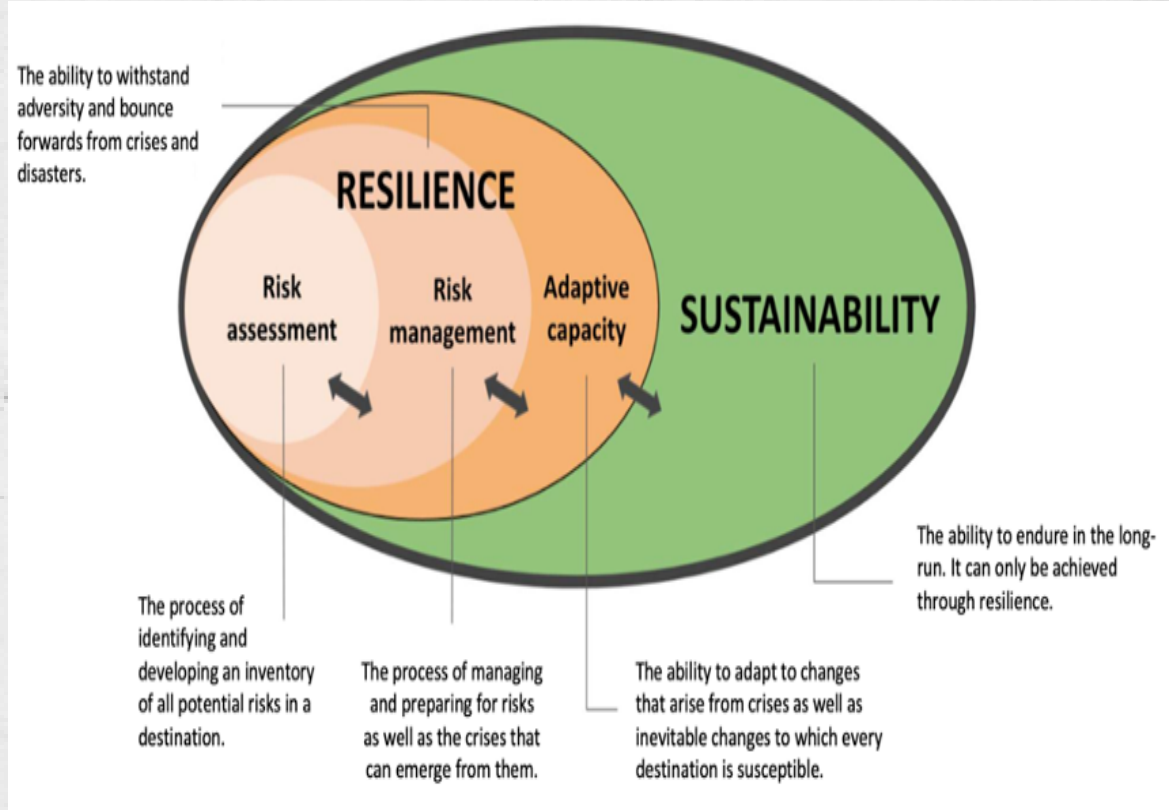
Resiliency is “the ability to *prepare* and plan for, *absorb*, *recover* from and more successfully *adapt* to adverse events or threats.”

National Academy of Sciences



Sustainability + Resilience

- Closely related but not the same thing!
- Sustainability: aimed at reducing environmental impacts of buildings and improved efficiency of resources
- Resilience: aimed at preparation for future hazards associated with climatic events/change



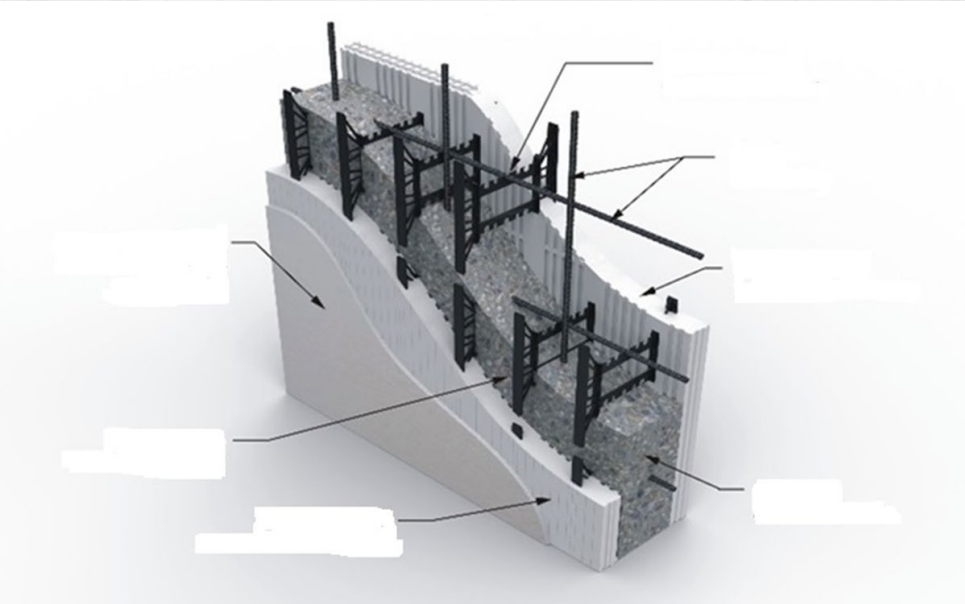
Ready Mixed Concrete

- Ready Mixed concrete plus insulation is a great combination.



Ready Mixed Concrete

- Ready Mixed concrete plus insulation is a great combination.
- The image shows an example of an insulated concrete form (ICF) wall. In this type of concrete wall, the outer edges are EPS insulation 2 ⅜″ to 2 ¾″ thick. This forms continuous insulation on both sides of the wall.

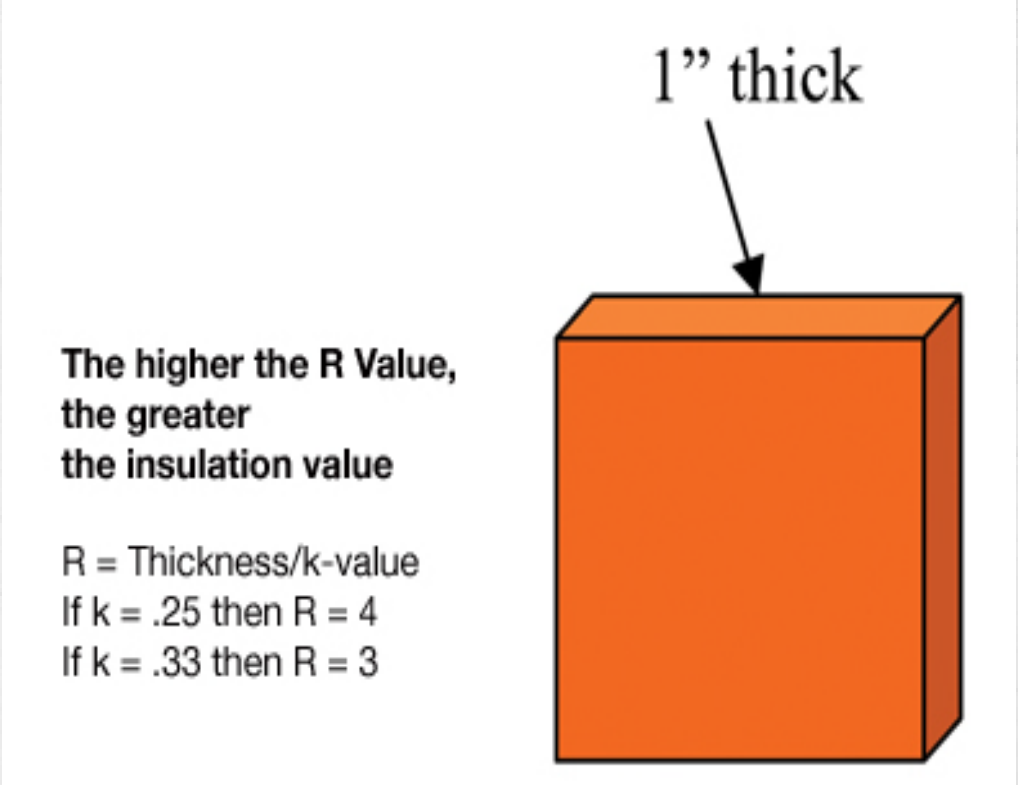


Thermal Resistance

- R-value
- The higher the better for insulation
- Not representative for mass walls because of the thermal mass properties

Thermal Resistance (R-value)

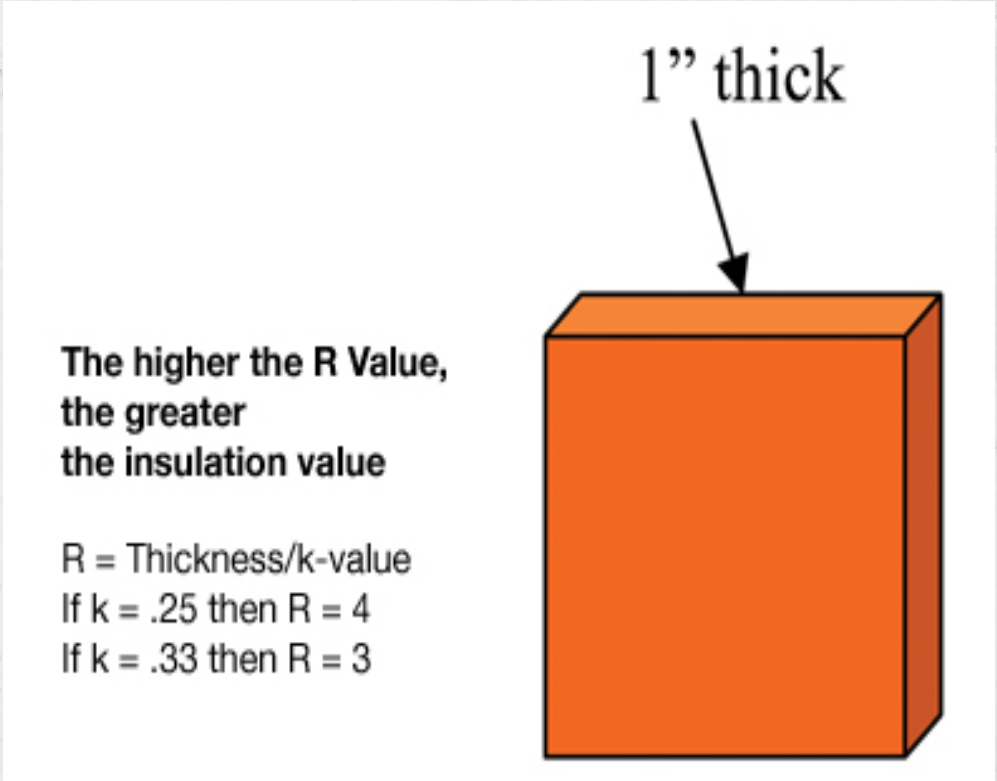
- Steady-State thermal property
- Good for insulation but doesn't give full picture for mass building envelope elements
- R-values are easier to understand and implement within the code



Thermal Conductivity (k-value)

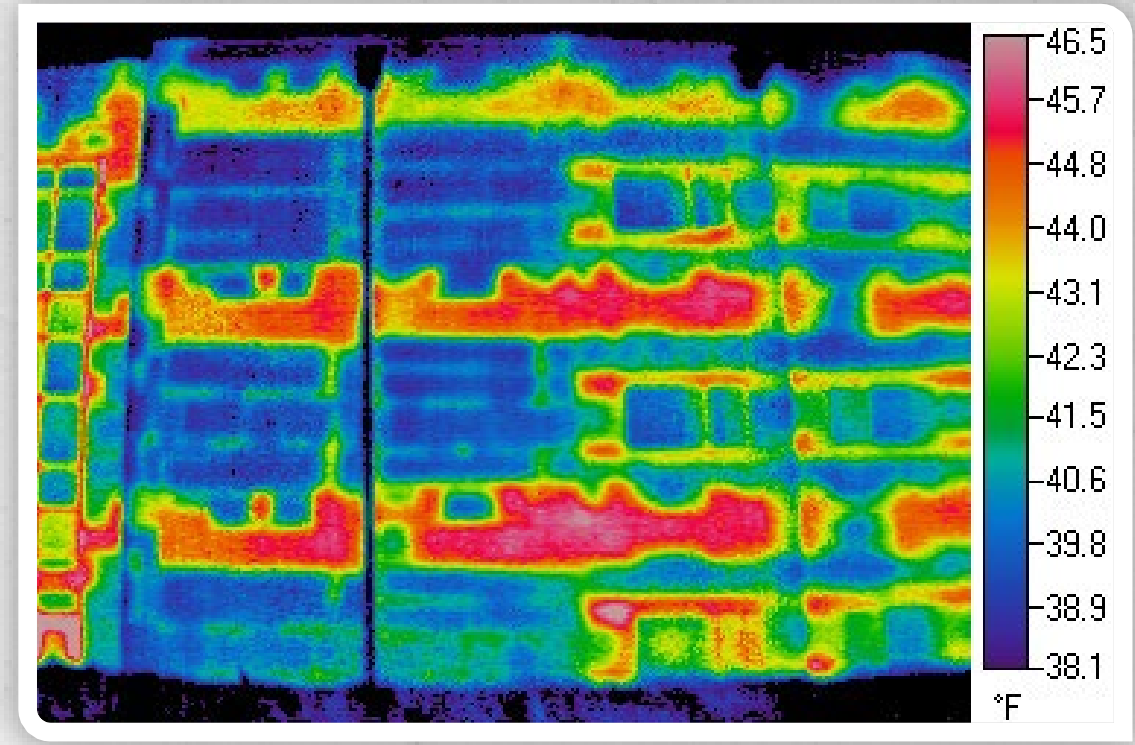
- Table showing the conductivities of various building materials

• XPS Insulation	0.2
• Wood	0.7
• Glass	16
• Concrete	16
• Steel	360

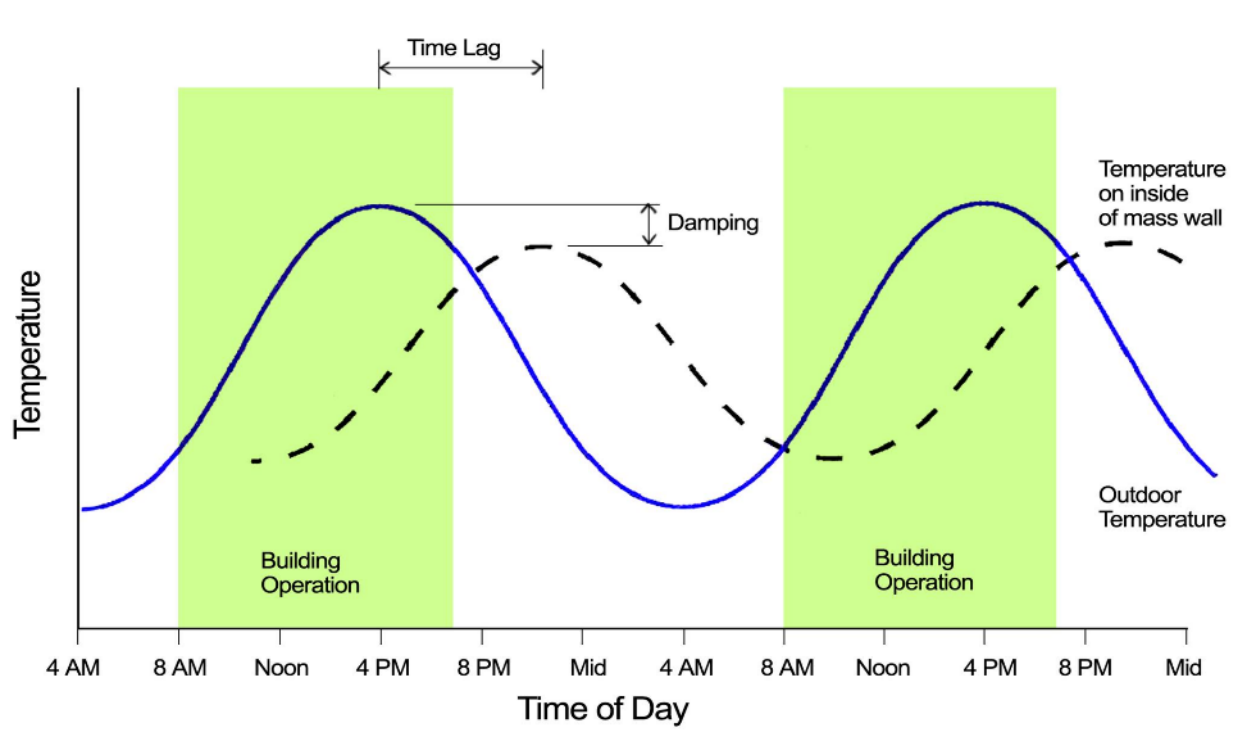


Thermal Bridges

- Heat seeks path of least resistance
- Some codes require calculation or test
- Isothermal Planes, Zonal Method, Hot box testing



Thermal Mass Effects



Thermal Mass Effects

- Reduce peak
- Delay peak load
- Reduce total load during many months in majority of Climate Zones
- On inside face, absorb internal heat gains from people, lighting, etc
- Works best with mass on the inside of the insulation: Precast and Tilt-Up sandwich wall panels



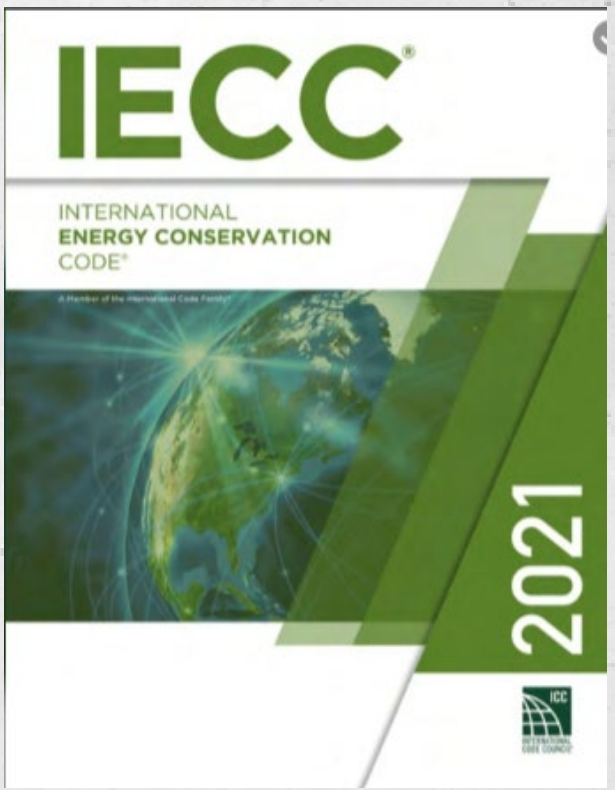
Energy Codes

- Required by Department of Energy for all buildings and sites except low-rise residential:
- This includes Commercial, Industrial, Justice, schools and Mid to High Rise residential



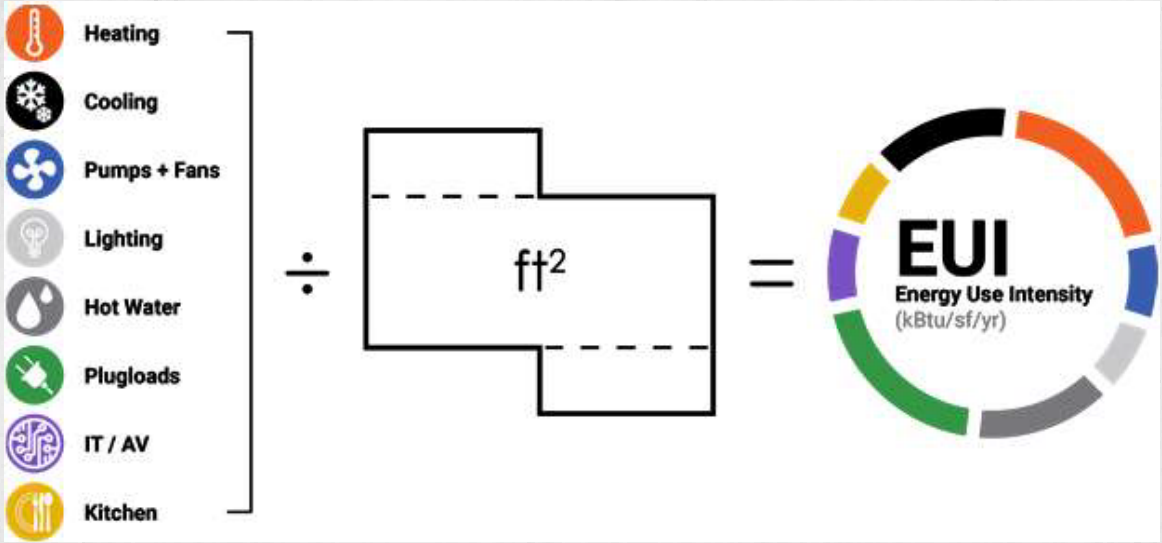
Energy Codes

- Commercial Building Envelope Requirements focus on:
- Thermal Performance
- Air-Barrier Performance
- Maximum Opening percentage



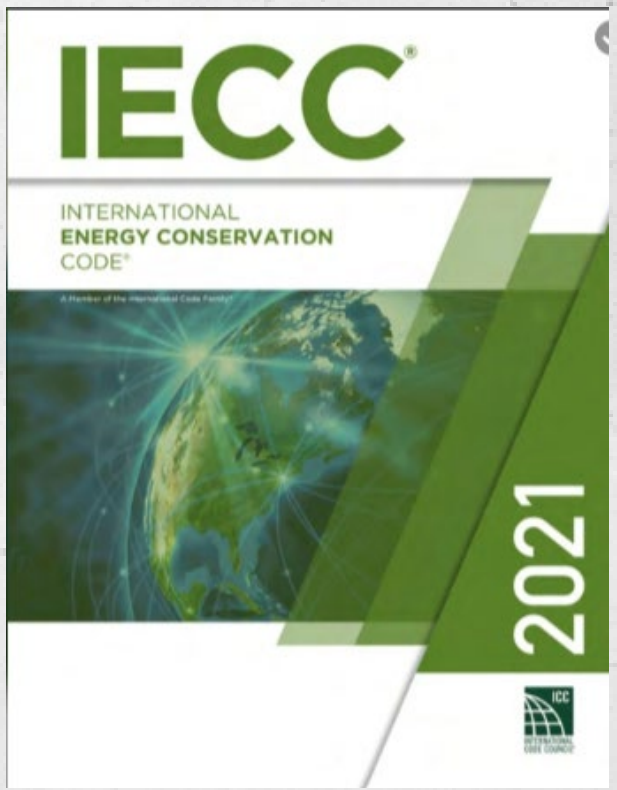
Energy Savings with ASHRAE 90.1

- ASHRAE 90.1 has reduced building EUI by over 50% since its inception



Prescriptive Criteria

- R-value min. per Section C402.1.3 & Table C402.1.3
- Max. fenestration per Section C402.4 & Table C402.4
- Air leakage per Section C402.5
  - Fenestration SHGC per Section C402.4.3
  - U-/C-/F-factor alternative per Section C402.1.4

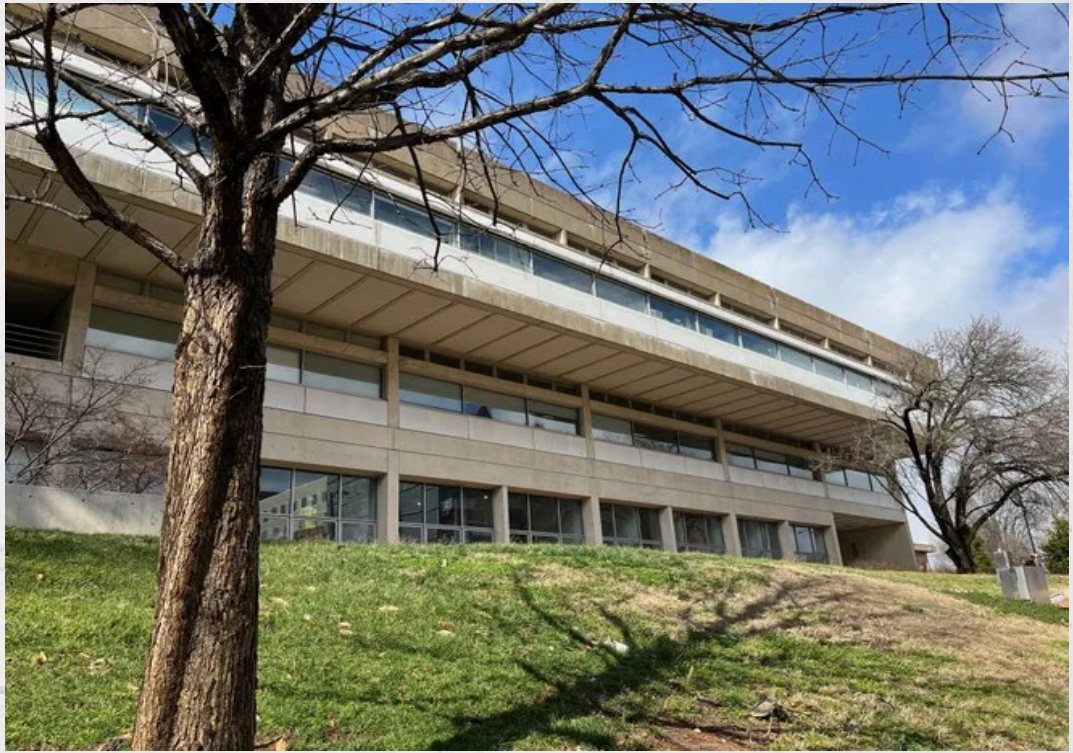


Compliance Paths: IECC v. ASHRAE

Compliance Approach	2021 IECC Path (Sec. C401.2.1)	ASHRAE 90.1-2019 Path (Sec. 5.1)
Prescriptive (R-value method)	Opaque assemblies meet minimum R-values in Table C402.1.3; fenestration per Section C402.4 (Sec. C402.1.3)	Prescriptive Building Envelope Option — component criteria in Tables 5.5-1 through 5.5-8 by climate zone (Sec. 5.5)
Prescriptive (U-factor alternative)	U-, C-, and F-factor assembly values in Table C402.1.4 permitted as an alternative to Table C402.1.3	Assembly maximum U-/C-/F-factors provided in the same Sec. 5.5 envelope tables
Envelope Trade-Off	COMcheck trades off envelope components against the Table C402.1.4 assembly baseline (Sec. C402.1.5)	Building Envelope Trade-Off Option (Sec. 5.6) — proposed envelope performance ≤ budget envelope
Whole-Building Performance	Total Building Performance (Sec. C407) — modeled annual energy cost ≤ standard reference design	Energy Cost Budget Method (Chapter 11) — modeled energy cost ≤ budget building

The 2021 IECC

- Model commercial energy code published by the ICC
- ASHRAE 90.1-2019 = alternate commercial compliance path (Sec. C401.2.2)
- Most widely adopted IECC edition among U.S. states
- Applies to commercial, industrial, and mid- to high-rise residential
- Adopted by states across every climate zone, 0 through 8



Building Envelope Performance

- Thermal Performance
  - Increase Insulation Thickness
  - Reduce Thermal Bridging
- Air Barrier Performance
  - Tight Seals and Openings
  - Reduced Air Infiltration
- Max. Opening Percentage
  - WWR
  - Advance Window Systems



Thermal Energy and Mass Walls

- Weigh not less than 35 pounds per square foot of wall surface area.
- Weigh not less than 25 pounds per square foot of wall surface area where the material weight is not more than 120 pcf
- Have a heat capacity exceeding 7 Btu/ft2× °F
- Have a heat capacity exceeding 5 Btu/ft2× °F where the material weight is not more than 120 pcf



Heat Capacity defined:

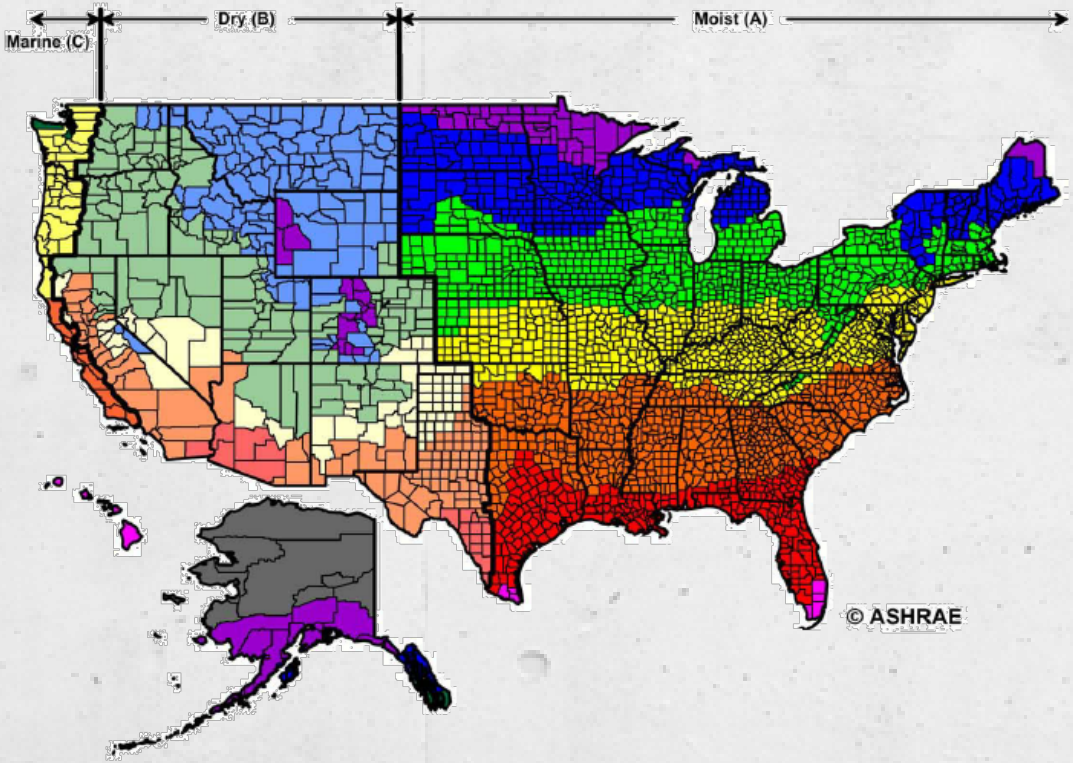
- Related to Specific Heat, Concrete density and concrete thickness
- Need to know this value to satisfy the requirements of code/standard

Heat Capacity requirement

- Mass walls and floors:
- ASHRAE 90.1 and IECC: HC ≥ 7.0 BTU/ft²·°F

• 3” Concrete	7.2
• 4” Concrete	9.6
• 6” Concrete	14.4

Climate Zones



- Zone 0A Extremely Hot Humid
- Zone 0B Extremely Hot Dry
- Zone 1A Very Hot Humid
- Zone 1B Very Hot Dry
- Zone 2A Hot Humid
- Zone 2B Hot Dry
- Zone 3A Warm Humid
- Zone 3B Warm Dry
- Zone 3C Warm Marine
- Zone 4A Mixed Humid
- Zone 4B Mixed Dry
- Zone 4C Mixed Marine
- Zone 5A Cool Humid
- Zone 5B Cool Dry
- Zone 5C Cool Marine
- Zone 6A Cold Humid
- Zone 6B Cold Dry
- Zone 7 Very Cold
- Zone 8 Subarctic

ASHRAE 90.1-2019
Mass vs. Framed Walls, CZ 3 & 4

- Prescriptive wall R-values — Table 5.5-3 & 5.5-4 (nonresidential)

Wall Type (Above Grade)	CZ 3	CZ 4 (exc. Marine)	Continuous insulation shown
Mass (concrete / CMU)	**R-9.5 ci**	**R-9.5 ci**	Lowest insulation burden — thermal mass credit
Steel-framed	R-13 + R-7.5 ci	R-13 + R-7.5 ci	Cavity + continuous required
Wood-framed & other	R-13 + R-3.8 ci	R-13 + R-3.8 ci	Cavity + continuous required

Source: ASHRAE 90.1-2019 Tables 5.5-3 & 5.5-4, nonresidential above-grade walls. 2021 IECC Table C402.1.3 lists equivalent values.

2021 IECC
Opaque Wall R-values by Climate Zone

- Table C402.1.3 — minimum insulation, all climate zones

TABLE C402.1.3
OPAQUE THERMAL ENVELOPE INSULATION COMPONENT MINIMUM REQUIREMENTS, *R*-VALUE METHOD[a]

CLIMATE ZONE	0 AND 1		2		3		4 EXCEPT MARINE		5 AND MARINE 4		6		7		8	
	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R
Roofs																
Insulation entirely above roof deck	R-20ci	R-25ci	R-25ci	R-25ci	R-25ci	R-25ci	R-30ci	R-30ci	R-30ci	R-30ci	R-30ci	R-30ci	R-35ci	R-35ci	R-35ci	R-35ci
Metal buildings[b]	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-25 + R-11 LS	R-30 + R-11 LS	R-30 + R-11 LS	R-30 + R-11 LS	R-25 + R-11 + R-11 LS	R-25 + R-11 + R-11 LS
Attic and other	R-38	R-38	R-38	R-38	R-38	R-38	R-49	R-49	R-49	R-49	R-49	R-49	R-60	R-60	R-60	R-60
Walls, above grade																
Mass[f]	R-5.7ci[e]	R-5.7ci[e]	R-5.7ci[e]	R-7.6ci	R-7.6ci	R-9.5ci	R-9.5ci	R-11.4ci	R-11.4ci	R-13.3ci	R-13.3ci	R-15.2ci	R-15.2ci	R-15.2ci	R-25ci	R-25ci
Metal building	R-13 + R-6.5ci	R-13 + R-6.5ci	R13 + R-6.5ci	R-13 + R-13ci	R-13 + R-6.5ci	R-13 + R-13ci	R-13 + R-13ci	R-13 + R-14ci	R-13 + R-14ci	R-13 + R-14ci	R-13 + R-14ci	R-13 + R-14ci	R-13 + R-17ci	R-13 + R-19.5ci	R-13 + R-19.5ci	R-13 + R-19.5ci
Metal framed	R-13 + R-5ci	R-13 + R-5ci	R-13 + R-5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-10ci	R-13 + R-10ci	R-13 + R-12.5ci	R-13 + R-12.5ci	R-13 + R-12.5ci	R-13 + R-15.6ci	R-13 + R-18.8ci	R-13 + R-18.8ci
Wood framed and other	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-7.5ci or R20 + R3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-18.8ci	R-13 + R-18.8ci
Walls, below grade																

Air Barrier and Mass Walls

- Air Leakage – 2021 IECC Section C402.5
- Cast-in-place and precast concrete naturally achieves air permeability well below the 0.004 cfm/ft² material threshold — easily satisfying the continuous air barrier requirement.
- The 2021 IECC sets a whole-building air leakage rate of 0.40 cfm/ft² at 75 Pa; sealed monolithic concrete assemblies readily comply, a natural advantage of concrete construction.



Max. Fenestration Area and Mass Walls

- 2021 IECC Section C402.4
- Maximum vertical fenestration: 30% of gross above-grade wall area
  - Increase up to 40% permitted where daylighting requirements are met (Sec. C402.4.1)
  - U-factor and SHGC limits per Table C402.4 by climate zone
  - Skylight area limited to 3% of roof area (Sec. C402.4)
  - Exceeding the maximum requires the performance



Design with Concrete

Concrete building systems are especially suited to provide resistance to natural hazards. Concrete has the necessary hardness and mass to resist the high winds and flying debris of tornadoes and hurricanes.

Concrete is fire resistant and non-flammable, which means it can contain fires and will not contribute to the spreading of fire. Reinforced concrete framing systems can be designed to resist the most severe earthquakes without collapse. Concrete doesn't rot or rust even if it is subject to flooding.



Photo credit: Tien Peng

In Summary

- 2021 IECC / ASHRAE 90.1-2019
  - ASHRAE
  - IECC
- R-values
  - Thermal bridges
- Savings energy important
  - Reduce owner bills
  - Energy code requirements are cost effective
  - Benefits to environment from less fuel use, less pollution
- Mass walls and thermal mass effects
  - Dependent on CZ and building types

Codes and Standards



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BUILD WITH STRENGTH



Thank you

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