energy and green building codes & standards

recognize CMU for its thermal mass

paths to compliance

by Martha G VanGeem, PE, LEED AP BD+C, FACI

Traditional masonry provides a durable, hard, relatively-smooth water-shedding surface that is beneficial especially as energy codes tend to require more insulation with each successive version.[1] The most common energy code adopted by US jurisdictions is the International Energy Conservation Code (IECC). In addition, ASHRAE/IES Standard 90.1 *Energy Standard for Buildings Except Low-Rise Residential Buildings* is a compliance path within the IECC for non-residential buildings, that is, commercial buildings and mid- to high-rise residential buildings four stories or more above grade. This article focuses on compliance for these types of buildings – all buildings that are not low-rise residential. Compliance can be shown using a prescriptive path, a simplified performance path or a performance path using a whole-building annual energy analysis. Benefits of masonry's thermal mass are accounted for in all three methods in the IECC and ASHRAE 90.1. However, energy simulations used to comply with the performance path need to be implemented in a particular manner in order for thermal mass to be recognized.

AIA CONTINUING EDUCATION

LEARNING OBJECTIVES

Upon reading the article you will be able to:

1. Differentiate between the three paths for energy code compliance.
2. Identify implementation methods for thermal mass to be recognized in the performance path.
3. Name properties of masonry wall material layers that contribute to its thermal mass.

Prescriptive Path: Preset Metrics

Meeting Minimums Prescriptive path entails complying with an R-value requirement from a table in the IECC or ASHRAE 90.1. Walls with a certain weight or heat capacity, defined as mass walls, require less insulation in the prescriptive tables than non-mass walls. Generally walls constructed of standard 8" concrete masonry units (CMU) or larger meet the definition of a mass wall.

Defining a Mass Wall In the 2012 IECC, mass walls are defined as those *weighing not less than (1) 35 psf of wall surface area or (2) 25 psf of wall surface area if the material weight is not more than 120 pcf*. This is essentially the same as the ASHRAE 90.1 definition of a mass wall, although the IECC uses psf of wall area as a metric whereas ASHRAE 90.1 uses heat capacity (HC) as a metric. The ASHRAE 90.1-2010 definition of a mass wall is *a wall with an HC exceeding (1) 7 Btu/ft²·°F or (2) 5 Btu/ft²·°F, provided that the wall has a material unit weight not greater than 120 lb/ft³*. ASHRAE 90.1-2010 Table A3.1C provides the heat capacity of concrete masonry walls that are fully grouted, partially grouted with empty cells, partially grouted with cells insulated, unreinforced with empty cells and unreinforced with insulated cells. A lower threshold for mass is provided for lighter weight masonry due to its greater thermal inertia.

The IECC and ASHRAE 90.1 require less insulation for mass walls than wood frame, metal frame, metal building or other walls not meeting the criteria for thermal mass. Table 1 presents the minimum R-value criteria for added insulation in colder climate zones representing Chicago or Detroit (Climate Zone 5) and Northern Michigan or Milwaukee (Climate Zone 6). Prescriptive requirements are based on cost effectiveness of adding insulation and not energy equivalence. Compliance can also be demonstrated using U-factors.

Simplified Performance Path: COMcheck

Substitution Method The simplified performance path is used to provide more flexibility than the prescriptive path. COMcheck software was developed by the US Department of Energy (DOE) for use in demonstrating compliance when not every component of the building envelope meets the requirements in the prescriptive tables of the IECC or ASHRAE 90.1. For example, if less insulation in the walls is desired by the designer, owner or builder, then COMcheck can be used to show what better performing windows or how much additional roof insulation can be used as an alternative. If more insulation is used in the above-grade walls than is required, then COMcheck can demonstrate where less insulation can be used elsewhere, for example in below-grade walls. The COMcheck program is relatively

[1]More insulation tends to lower the temperature of the cold side of the wall (interior in the summer and exterior in the winter) causing more potential for moisture problems. Traditional masonry walls help prevent moisture problems by keeping moisture from precipitation out of walls.

Table 1 - Minimum Prescriptive Insulation Requirements for Commercial Building Walls in 2012 IECC and ASHRAE 90.1-2010

	IECC				ASHRAE			
	Climate Zone 5		Climate Zone 6		Climate Zone 5		Climate Zone 6	
	Nonresidential	Residential	Nonresidential	Residential	Nonresidential	Residential	Nonresidential	Residential
Mass	R-11.4 ci	R-13.3 ci	R-13.3 ci	R-15.2 ci	R-11.4 ci	R-13.3 ci	R-13.3 ci	R-15.2 ci
Wood frame	R-13+R-3.8 ci	R-13+R-7.5 ci	R-13+R-7.5 ci	R-13+R-7.5 ci	R-13+R-3.8 ci	R-13+R-7.5 ci	R-13+R-7.5 ci	R-13+R-7.5 ci
Metal frame	R-13+R-7.5 ci	R-13+R-7.5 ci	R-13+R-7.5 ci	R-13+R-7.5 ci	R-13+R-7.5 ci	R-13+R-7.5 ci	R-13+R-7.5 ci	R-13+R-7.5 ci
Metal building	R-13+R-13 ci	R-13+R-13 ci	R-13+R-13 ci	R-13+R-13 ci	R-13+R-5.6 ci	R-13+R-5.6 ci	R-13+R-5.6 ci	R-13+R-5.6 ci

ci indicates continous insulation. Mass walls require the least amount of added insulation due to their inherent thermal mass.

user-friendly and requires relatively simple inputs such as type of building, building dimensions, insulation in opaque portions of the building envelope, and type of windows (or more accurately, fenestration or glazing).

Performance Path: Energy Modeling

Opportunity for Most Energy-Saving Measures The IECC and ASHRAE 90.1 allow a more complex performance path. A reference building meeting prescriptive requirements, as well as a proposed building, are each modeled using energy software that simulates building energy use for every hour for an entire year using average weather data. The annual energy cost for the proposed building must be less than the annual energy cost for the reference building. This provides a great deal of flexibility in energy-saving measures, such as insulation or daylighting, used in the buildings.

In states where energy codes have long been in place such as California or Florida, most buildings are shown to comply using a performance path due to its flexibility in choosing energy-saving measures. The upfront cost of energy simulations is offset by lower material costs compared to complying with prescriptive requirements. Reducing insulation in mass walls is a common result of using the software and complying with the performance path. The software can also be used to account for the energy-saving thermal mass benefits of clay brick even though walls with traditional brick veneer are not considered mass walls by the IECC and ASHRAE 90.1.

Using the performance path requires an understanding of complex software as well as the required inputs for the building envelope: heating, ventilation, cooling and lighting. Most simulators use EnergyPlus or DOE2-based simulation programs. Both of these can be used to show the benefits of thermal mass. EnergyPlus more accurately simulates thermal mass effects and is more likely to show more energy savings when thermal mass is used than DOE2-based programs. However, DOE2-based software programs generally require less time to learn and are easier to use.

Dynamic Modeling Thermal mass effects that save energy are due to dynamic effects (hourly changing temperature conditions) rather than steady-state effects (constant temperature conditions). Dynamic modeling capabilities are more complicated than steady-state, so EnergyPlus and DOE2 have default options that allow the input of steady-state R-values or U-factor properties for walls rather than the more complex wall properties required for dynamic analysis. When the familiar steady-state properties are input, the thermal mass effects of the walls or other building envelope components are not accounted for, and this is not readily known by some users. **Therefore it is important for the software user to understand how to input the wall properties that will turn-on the thermal mass effects of EnergyPlus and DOE2-based software.**

Using EnergyPlus, several material *types* may be used to describe layers within opaque construction components, including walls. The opaque types allowed to be chosen by the user are:

- Material
- Material: NoMass
- Material: AirGap
- Material: RoofVegetation
- Material: InfraredTransparent

Material is the preferred type of material in EnergyPlus and accounts for the dynamic thermal properties of the material. It allows EnergyPlus to take into account the thermal mass of the material and thus allows the evaluation of transient conduction effects. *Material: NoMass* is similar in nature but only requires the thermal resistance (R-value) rather than the thickness, thermal conductivity, density and specific heat. Note that using a simple R-value-only material forces EnergyPlus to assume steady state heat conduction through this material layer.[2] To invoke thermal mass effects in EnergyPlus, values of thickness, thermal conductivity, density and specific heat must be entered for each layer of material in the exterior wall or building envelope component.

DOE2-based software programs are similar to EnergyPlus in this regard. In order to benefit from the thermal properties of walls using VisualDOE,[3] various layers of the wall must be defined using the VisualDOE Construction Editor. A construction is composed of individual layers of materials. Individual materials should be defined according to their material properties, such as thickness, thermal conductivity, density and specific heat. When several layers of materials are combined to form a construction, the texture, emissivity and absorptance must also be specified. For common building materials, the VisualDOE 4.0 User Manual[4] gives typical values. Similarly, eQUEST, another DOE2-based program, requires the *Layers Input* for the program to assign thermal mass to the construction. Using *U-Value Input* will use only steady-state properties of the wall.

Values for specific heat and thermal conductivity of concrete are available in the *ASHRAE Handbook of Fundamentals*.[5] Care must be taken to use values with the appropriate units for the simulation program being used.

To invoke thermal mass benefits of interior walls using EnergyPlus and DOE2-based software programs, these walls must also be input as layers with their individual thermal properties of thickness, thermal conductivity, density and specific heat. Using default partition walls or using overall R-value or U-factor as inputs will cause these walls to not be simulated as mass walls. Buildings modeled with VisualDOE, for example, contain interior partitions by default. If the partition walls are lightweight, such as steel studs and gypsum wallboard, their thermal mass is insignificant. However, for concrete masonry partition or shear walls, the mass should not be ignored. The mass of the actual masonry partition walls must be compared to the default arrangement of partition walls. If the mass differs, thickness of partition walls should be adjusted to reflect the actual situation. For example, if the modeling scenarios have interior masonry walls, the total volume of the masonry walls in the building should be distributed over the VisualDOE default partition wall area. More information is provided in *Modeling Energy Performance of Concrete Buildings for LEED-NC Version 2.2: Energy and Atmosphere Credit 1*.[6]

Green Building Rating Systems

Rely on Codes and Standards LEED 2009[7] compliance with minimum energy performance requirements and credits to optimize energy performance generally require whole building energy simulations similar to those described in the performance path above. The same precautions should be taken when complying with LEED or determining LEED credits – wall layer properties must be entered individually and must include properties such as density and specific heat in order for the component to be modeled as thermal mass.

LEED 2009 also has prescriptive paths for complying with minimum energy performance requirements and credits to optimize energy performance. One path is to comply with various *ASHRAE Advanced Energy Design Guides (AEDGs)*.[8] Complying with the *AEDGs* is not always cost-effective for masonry; the *AEDGs* are not consensus documents, did not undergo a public review process and are not based on cost-effectiveness. When comments on mass wall criteria were submitted during the development of these, the response was always that the prescriptive tables are only one method of achieving energy savings.

The International Green Construction Code (IgCC)[9] and ASHRAE/USGBC/IES Standard 189.1 on high performance green buildings[10] have similar performance paths for complying with energy performance requirements. ASHRAE 189.1 is a compliance option of the IgCC – when complying with the *IgCC*, the user can comply with either ASHRAE 189.1 or Chapters 2 through 12 of the IgCC. ASHRAE 189.1 and the IgCC are not point or rating systems like LEED; rather, they have minimum requirements. This provides a more direct application for their use and for their adoption into local codes. More information on complying with energy requirements for *ASHRAE 189.1* is available.[11,12]

When demonstrating energy compliance with a performance path in an energy or green building code or standard, masonry wall components should be entered as individual layers including properties such as thickness, thermal conductivity, density and specific heat. Entering the wall properties using R-value or U-factor will cause the software to ignore its thermal mass effects.

---

[2] *The Encyclopedic Reference to EnergyPlus Input and Output*, October 2011. http://apps1.eere.energy.gov/buildings/energyplus/pdfs/programmingstandard.pdf

[3] Architectural Energy Corporation

[4] Architectural Energy Corporation

[5] ashrae.org

[6] Marceau, ML, and VanGeem, MG. 2006 *Modeling Energy Performance of Concrete Buildings for LEED-NC Version 2.2: Energy and Atmosphere Credit 1*. R&D Serial No. 2880a, Portland Cement Association.

[7] US Green Building Council, usgbc.org

[8] There are now 12 AEDGs available for free download from ASHRAE ashrae.org/standards-research--technology/advanced-energy-design-guides

[9] iccsafe.org

[10] ashrae.org

[11] VanGeem, MG and Lorenz, E. *Understanding ASHRAE 189.1. The Construction Specifier*. October 2011.

[12] Kennedy, SD, Lawrence, T and VanGeem, MG. *Energy Efficiency: Building on Standard 90.1. ASHRAE Journal's Guide to Standard 189.1*, June 2010.

Martha G VanGeem, PE, LEED AP BD+C, FACI, is a self-employed principal engineer in the Chicago area with 35 years of experience. She serves as a project principal investigator and specialized consultant in the areas of green buildings and infrastructure, energy use in buildings, energy codes, thermal mass and moisture mitigation. In the area of green technologies, VanGeem provides expertise on LEED and other green rating systems, product category rules (PCRs), environmental product declarations (EPDs) and life-cycle assessments (LCAs). She is a member of many energy and green building standards committees including those within ASHRAE, ACI and ASTM. She is a fellow of the American Concrete Institute and has authored more than 100 publications. VanGeem received her bachelor's degree of civil engineering from the University of Illinois (Urbana) and her MBA from the University of Chicago. **vangeemconsulting.com 847.259.6338**