Insulated Cavity Masonry Wall Design: Maximizing Energy Performance

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The continually rising cost of energy along with concerns about a dwindling amount of natural resources remain critical concerns of most building owners, architects, engineers and builders. The current energy code in Michigan for nonresidential buildings includes the language that buildings meet ASHRAE 90.1-1999, *Energy Standard for Buildings Except Low-Rise Residential Buildings.* Energy codes typically provide minimum levels of energy performance for each component of the building envelope. Programs like LEED (Leadership in Energy and Environmental Design), developed by the US Green Building Council, provide certification to buildings that surpass these minimum levels of energy performance outlined in state energy codes. Design professionals and owners are often left with the question: How can we increase building envelope performance and decrease energy costs in our buildings? The use of an insulated cavity masonry wall can provide methods to maximize energy performance beyond the minimum code requirements for the life of the structure.

Understanding Material Thermal Properties

By utilizing masonry and insulation in cavity wall construction, designers may reap benefits from the inherent properties of each material, providing energy and cost savings. Masonry is traditionally known for durability, maintainability, strength, fire resistance, noise control, minimal embodied energy, economic costs, aesthetic and design flexibility, but also provides great thermal benefit. The additional properties of insulation, whether batt-type, foam bead, loose fill, foam panel or spray applied, resist heat flow, helping to improve comfort, indoor air quality, envelope tightness and energy performance. A successful insulated cavity masonry wall combines the properties of masonry and insulation in a system that makes it possible to surpass minimum energy requirements and achieve additional "Optimized Energy Performance" credits from LEED. It is critical to give attention to masonry and insulation selection early in the design process and to understand their thermal properties to achieve the desired envelope performance and energy savings.

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Material thermal properties are often in values expressed numerically and are fundamental to communicating and understanding any dialogue of heat flow within a building envelope. Materials like masonry and insulation are widely available in standard thicknesses. Each material has a known rate of heat flow for each standard material thickness. This rate is known as Conductance (designated as C). The ability of that material to resist heat flow and act as an insulator is known as Resistance, or "R-value." R-values are useful when comparing insulation and are typically listed as "per inch of thickness." The higher the R-value of a material, the greater its resistance to heat flow. The reciprocal of the R-value ($1 \div R$) is known as the "U-value," or the rate of heat loss. U-value is the overall coefficient of heat transmission of a system of materials and is equal to the total reciprocals of all material R-values. U and R-values are used in building envelope calculations when meeting energy code requirements.

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Learning Objectives

After reading this article, you will have learned:

1. How the thermal properties of materials in a wall system are calculated and expressed
2. How an insulated masonry cavity wall will surpass minimum energy requirements for a building
3. How computer-based programs can perform whole building energy analysis to determine energy savings of insulated cavity wall systems

See page 98 for test and answer form.

Thermal properties of masonry can vary greatly according to wall design and density of the CMU selected. Material density, expressed in pounds per cubic foot (lb/ft^3) of CMU, is directly related to the R-value. ASTM C90 *Standard Specifications for Loadbearing Concrete Masonry* allows for three weight classifications of CMU:

Normal Weight	≥ 125 lb/ft^3
Medium Weight	≥ 105 < 125 lb/ft^3
Light Weight	< 105 lb/ft^3

The lower the density of the CMU — the higher the R-value, however, grout spacing and reinforcing must additionally be considered. The amount of grout and reinforcing within a wall system as determined by building height, load and structural framing requirements will increase the conductance (thus lowering the R-value), and is critical when considering insulated cavity masonry wall design.

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Thermal Mass Efficiency

The density of masonry used within an insulated cavity wall system will naturally provide varying thermal mass properties. Thermal mass refers to the capacity to absorb and retain heat. The absorption and retention of heat by masonry provides several benefits contributing to increased energy performance. By slowing the transfer of heat or cold through the building envelope, temperature fluctuations can be minimized. Indoor temperatures are additionally moderated when masonry remains warm or cool after HVAC equipment is shut off reducing peak heating and cooling loads. This reduction in peak heating and cooling loads shifts demand to off-peak hours often resulting in reduced energy costs by avoiding peak utility rate periods. In Michigan, energy suppliers have discounted rates for commercial and industrial applications of power use during these off-peak times.

Dependent upon the actual amount of heating and cooling load reduction due to thermal mass, HVAC system sizing could be affected. Before reducing HVAC system sizing, some factors should be considered such as climate, internal loads and time lag. In climates where there are large daily temperature fluctuations above and below the building balance point temperature, thermal mass provides the greatest benefit. In Michigan, seasonal change demands that a mechanical system provide both heating and cooling. In Michigan, however, being a heating dominated climate, the greatest benefits of thermal mass are used to absorb and retain heat. Absorbed thermal energy, which is often underutilized, is provided by solar gain from the sun. Maximized by proper building orientation, solar gain can affect HVAC systems helping to additionally shift peak demand to off-peak hours.

Internal loads generated from occupancy, equipment, lighting and building operational times have effects on cooling and heating energy consumption, which can minimize thermal mass benefits due to the time lag of masonry. Time lag is the amount of time for heat to transfer through a material. A masonry cavity wall has a time lag of six hours (per ASHRAE Fundamentals Handbook) helping to reduce heat loss or gain through the wall. By incorporating thermal mass properties of masonry into a building's design and understanding the interrelationship between these factors on heating and cooling demands, HVAC systems can be sized to maximize energy efficiency and reduce equipment costs.

Insulated Cavity Masonry Wall Systems

Insulated cavity masonry wall systems combine the natural material and thermal efficiency properties of masonry and insulation to provide a method to maximize energy performance. The construction of an insulated cavity masonry wall system primarily consists of brick veneer or concrete masonry units separated by a varying dimensional air gap, insulation, mortar, grout, anchorage systems, movement control and moisture barriers. Each component of the wall system, whether backed up with CMU or metal studs, requires detailing, quality materials, installation accuracy and scheduling coordination of multiple trades to avoid performance failure. Any single failure can result in water damage, expensive repairs, maintenance costs, health concerns due to mold and excessive air infiltration.

Masonry units and insulation in elementary form are not expensive materials. Cost is accumulated due to manufacturing infrastructure, energy used in production, transportation and jobsite installation. Costs may vary among types of masonry cavity walls as a result of specification and design details. Masonry material costs and R-values are displayed in Table 1 reflecting these additional costs.

MASONRY MATERIAL	R-VALUE	COST/SF INSTALLED
Normal Weight	2.0	$9.35
Medium Weight	2.1	$8.90
Light Weight	2.2	$8.45
Brick Veneer	0.4	$13.30

Table 1. R-Values and Costs for Masonry
[References: NCMA TEK 6-2A (2005), RSMeans Building Construction Cost Guide (2007)]

INSULATION MATERIAL	R-VALUE PER INCH OF THICKNESS	COST/SF INSTALLED
Perlite	2.7	$0.82
Rigid (Extruded Polystyrene)	5.0	$1.09
Foam Fill	3.34	$2.97
Foam Spray	3.8	$2.16

Table 2. R-Values and Costs for Insulation
[Reference: NCMA TEK 6-2A (2005)

ASSEMBLY NO	COMPONENT	ASSEMBLY U-FACTOR	ASSEMBLY R-VALUE	COST/SF INSTALLED
Assembly 1	8˝ CMU – Medium Weight 2˝ Airspace + Air Film 4˝ Clay Masonry	U = 0.19	R = 5.3	$21.69
Assembly 2	8˝ CMU – Medium Weight Perlite 2˝ Airspace + Air Film 4˝ Clay Masonry	U = 0.13	R = 7.7	$22.51
Assembly 3	8˝ CMU – Medium Weight Core – Foam Fill 2˝ Airspace + Air Film 4˝ Clay Masonry	U = .126	R = 8.0	$24.66
Assembly 4	8˝ CMU – Medium Weight 2˝ Rigid Insulation 2˝ Airspace + Air Film 4˝ Clay Masonry	U = 0.06	R = 16.7	$25.99
Assembly 5	8˝ CMU – Medium Weight Core – Foam Fill 2˝ Foam Spray 2˝ Airspace + Air Film 4˝ Clay Masonry	U = 0.05	R = 20.0	$28.40

Table 3. Assembly U-Factors for Insulated Masonry Cavity Walls
[References: NCMA TEK 6-2A (2005), Story Pole Masonry Resource Guide *2007 Masonry Wall Cost Guide,* RSMeans Building Construction Cost Guide (2007)]

Building envelopes utilizing cavity wall construction that provide more than the minimum amount of insulation required by energy codes assist in additional thermal savings not comparable to conventional framed masonry veneer walls. According to the Alliance to Save Energy, a typical pound of insulation saves 12 times the amount of energy required for material production during the first year of use and continues to pay benefits throughout the life of the building in which it is installed. The relationship between insulation R-value and costs is displayed in Table 2.

Additional benefits resulting from certain insulation types include: reduced air infiltration and thermal bridging, resistance to mold, higher sound transmission coefficient (STC) ratings, possible fire resistance, waterproofing and barriers to pest invasion. These benefits may prove to outweigh the initial cost of the material.

Energy Standards

Information in Table 3 helps to reinforce the fact that increased insulation provides lower U-values of wall assemblies. Increased insulation is associated with increased cost dependent largely upon the labor of installation. The use of rigid insulation is shown to provide significant thermal value with a minimal increase in installation costs. However, in order to maximize energy performance and fully recognize the material and thermal properties of insulated cavity masonry wall construction, a complete understanding of minimum energy performance is required. Energy code compliance software is a valuable complement to current printed standards. Many types of software have been developed to help determine code compliance, one of which is COMcheck.

COMcheck, provided by the US Department of Energy, (available at http://www.energycodes.gov/comcheck/) is free downloadable code compliance software which is user friendly. COMcheck can help confirm compliance with most commercial energy codes based on ASHRAE/IESNA Standard 90.1. The software allows users to input a description of building size, location, type, envelope, lighting and HVAC components. Input data is then compared to integral data bases of code requirements, material thermal properties and weather data to determine compliance and percentage of optimization beyond minimum code requirements.

Energy Savings

Energy savings of an insulated cavity masonry wall system cannot be fully acknowledged without the use of whole building energy analysis. This approach to energy analysis accounts for all aspects of a building's energy use beyond the basics of the building envelope for yearly energy consumption, calculated on an hourly basis. Computer based programs like DOE2, http://www.doe2.com/, and EnergyPlus, http://www.eere.energy.gov/buildings/energyplus/ both available for free download, provided by the US Department of Energy, are capable of calculating yearly energy savings. These yearly energy savings are compared to a baseline building design and can give an accurate prediction of energy use. However, consideration should be taken to make sure current energy prices are utilized when estimating annual energy costs to provide realistic results when using this software.

By incorporating thermal mass properties of masonry into a building's design and understanding the interrelationship between these factors on heating and cooling demands, HVAC systems can be sized to maximize energy efficiency and reduce equipment costs.

Computer based programs like DOE2 and EnergyPlus give designers methods to test energy saving strategies. However, it is still important not to compromise occupant comfort when seeking energy savings. Worker productivity is related to occupant comfort. Any decrease in occupant comfort can result in loss of revenue greater than the cost of energy operation, including the savings. Standards like ASHRAE 55-1992 and ASHRAE 62-1999 consider occupant comfort levels and should not be overlooked when analyzing energy savings.

Insulated Cavity + Analysis = Maximized Energy Performance

The use of an insulated cavity masonry wall involves the understanding of material and thermal properties for proper cost effective material selection and maximized energy savings. With the current availability of software like COMcheck, designers have

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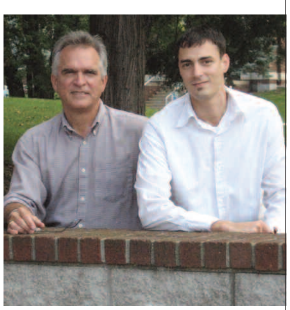
an understanding of minimum energy code compliance providing a baseline for optimization. Increasing insulation within a cavity masonry wall does provide energy savings and a cost effective method to optimize energy performance throughout the life of the building. However, to fully acknowledge energy performance, whole building energy analysis should be utilized. Owners, architects, engineers and builders who utilize an insulated cavity masonry wall and verified their design with energy analysis have taken a critical step in increasing building envelope performance and decreasing energy costs. This critical step, besides decreasing energy costs, is helping to decrease demands on our limited natural resources, helping to protect and preserve for future generations.



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