Rebirth of Single Wythe Masonry

Evolving Technology Responds to Tighter Energy Codes

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and Ed Weinmann, LEED Green Associate

Rise of Energy Codes

Increased focus on energy efficient buildings has led to building envelope performance coming under scrutiny. Public awareness of the effects of greenhouse gas emissions (GHG) and climate change grew rapidly toward the end of the 20th Century. The first versions of the International Energy Conservation Code (IECC) and LEED were published in 2000. Canada’s National Energy Code for Buildings 2011 replaced the original Model National Energy Code for Buildings from 1997. Each presented new ways of thinking about the role of the built environment, both its materials aspects and minimum performance expectations. Today, 39 states and Washington DC have adopted a version of the IECC from 2009, or later.

Architects 2030, a non-profit, non-partisan and independent organization, issued The 2030 Challenge in 2006 asking the global architecture and building community to become part of the solution to reducing greenhouse gas emissions by adopting incremental targets of fossil fuel energy reduction toward the goal of buildings being carbon neutral (using no fossil fuel GHG-emitting energy to operate) by 2030. Many organizations, universities, public and private businesses and governments throughout the US, Canada and the world have risen to the challenge. As such, building methods and materials continue to be evaluated for their contribution to energy efficient buildings.

Paths to Code Compliance

There are three paths to complying with the IECC. All paths lead to buildings designed to meet code, but each has a different objective and different level of complexity. The first and simplest is the prescriptive method. This entails choosing wall materials at or above a prescribed R-value minimum or...
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1. U-values based on NCMA's Thermal Catalog of Concrete Masonry Assemblies, Second Edition.
2. Poured-in place block polyurethane insulation (R-5.91/inch) in ungrouted cells.
3. Extruded polystyrene (R-5/6 inch).
4. Units have 2 cells and 3 webs: faceshells = 1.25 inch, webs = 1.00 inch.
5. Units have 1 cell and 2 webs: faceshells = 1.25 inch, webs = 0.75 inch.
6. Units have 0 cells and 1 web: faceshells = 1.25 inch, webs = 0.76 inch.

Alternatively, choosing a wall assembly at or below a prescribed U-factor maximum identified in the code, section 502.1 in 2009 IECC. The second path is system performance which takes into account the entire building envelope—roof, walls, floors—not just the wall. The third and most complex path is whole building energy analysis. This method takes into account the whole of the building's energy usage over the period of a year and compares it to another baseline building of the same type. While prescriptive is the simplest, there is a lot of variance possible in determining whether a material or assembly will meet code requirements.

**Prescriptive Tables** A few years ago, this emphasis on building envelope energy efficiency had industry professionals examining energy codes and anticipating the decline of single wythe masonry as a viable wall construction method, particularly in colder climate zones. Main challenges single wythe design faces can be attributed to two factors:

- R-value becoming a key measure in the effectiveness of building products to insulate and
- Misconceptions surrounding the meaning of continuous insulation (CI).

There has been a continual increase of minimum R-value of the insulation required for wall design and construction in energy and building codes. Energy design by prescriptive R-value is not an effective indicator of a building's energy performance. Increased R-value requirements necessitated designing for additional insulating materials on the interior and/or exterior of a masonry wall.

Technically, R-value (Thermal Resistance) is defined in the IECC as the inverse of the time rate of heat flow through a body from one of its bounding surfaces to the other for a unit temperature difference between two surfaces, under steady state conditions per unit area (the thermal resistance one square foot of material has over the course of an hour). The test for R-value is performed in the guarded hot box, where a steady state condition is established, as per ASTM C1363 Standard Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus.

Guarded hot box R-value testing and assessing does not account for the dynamic world in which we live (fluctuation in sunlight, temperature, humidity, pressure, wind, etc.). Hot box test methodology bypasses or eliminates the real world physical principles of thermal mass, thermal lag, and thermal flywheel effect offered by mass (its ability to store heat, slowly release it over time, flattening temperature fluctuations). It could be debated that since the test bypasses or does not properly account for differing physical properties of materials, it cannot be an accurate test of any material's performance.
Table 2 – Summary of Mass Wall Min R-value or Max U-factor

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<th>Climate Zones</th>
<th>Rmin Insulation</th>
<th>Umax Assembly</th>
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<tr>
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<td>5.7 ci</td>
<td>0.580</td>
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<td>2</td>
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<tr>
<td>6</td>
<td>15.2 ci</td>
<td>0.071</td>
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1ci, 2ci is allowed to be substituted with concrete block walls complying with ASTM C90, ungrouted or partially grouted at 32° or less on center vertically and 48° or less on center horizontally with engorged cores filled with materials having a maximum thermal conductivity of 0.44 Btu-in/h·ft·°F.

R-value minimum of the insulation only, as a stand-alone narrative, is an incomplete method of setting the design parameters for a building’s thermal performance. While R-value (calculated) may be a piece of the energy efficiency puzzle, it is just that, a piece.

Maximum U-factor of the assembly is an accepted alternative to the Minimum R-value requirement of the insulation only for prescriptive code compliance. U-factor (Thermal Transmittance) is the measure of thermal energy transmission through a building. U-factor of the assembly is the reciprocal of the total (additive) R-value of the components that make up the assembly. \( U = \frac{1}{\sum R_i} \) (Ri = R1 + R2 + R3...)

That continuous insulation (CI) is a mandatory requirement remains a longstanding misunderstanding of the IECC. The prescriptive minimum R-value table (Table C402.2.1 in 2009 IECC, C402.1.3 in 2015 IECC) provides requirements for continuous insulation. This table does not take into account inherent thermal properties of other parts of the assembly (CMU for example). However, prescriptive compliance can also be achieved through [maximum U-factor table (C502.1.2 in 2009 IECC)] C402.1.4 in 2015 IECC), which provides overall assembly U-factor maximums.

When choosing this prescriptive compliance path, the entire assembly is considered in determining compliance, and continuous insulation is not required. Additionally, it is not necessary to comply with both tables. It is recommended to use the U-factor table when choosing prescriptive compliance for most concrete masonry walls (especially single wythe).

Single wythe systems may function as both enclosure and finish, so they may not be designed to apply continuous insulation on the exterior or interior faces of the CMU. Because there are several aesthetic enclosure materials desired by owners and designers that cannot be designed to comply with the continuous insulation mandate, curtainwall among them, there are other ways to comply with code minimums. A project need only comply with one of three methods for energy code compliance, not all.
Insulated Concrete Masonry

OmniBlock is a patented insulated cementitious masonry unit (CMU) structural wall system combining benefits of indigenous aggregates, expanded polystyrene, thermal lag, exposed thermal mass and air tightness in a durable, fire resistant product. Omni Block reduces thermal bridging with set-off cross webs and middle internal wall configuration. Combined with two layers of insulation in the 8” and 10” system, and three layers in the 12” system, results are high thermal performance, extremely quiet buildings, low energy consumption, high fire rating and low maintenance.

emco-block.com | 301.927.8900
omniblock.com | 877.711.6654

InsuTech™ Concrete Masonry System from Oldcastle offers high thermal efficiency in an innovative design system. It is 100% thermally broken, providing continuous insulation even in corners. The InsuTech System includes a pre-assembled structural masonry unit available in standard finishes as well as Trenwyth® colors and finishes. Interior face may be a different color and textural finish from exterior face. lenbrowning@oldcastle.com | 844.495.9211
InsuTechSystem.com

Hi-R H Masonry unit has been designed to provide reduced thermal bridging. Block and insulation are combined prior to site delivery. Permits full grout and reinforcement of wall without removing insulation. Shape permits efficient installation even with placement over reinforcement for fully grouted walls. Capable of meeting IECC (2009) R-value thresholds in all climate zones. Provided with precision face and architectural decorative face units in 12” by a network of concrete products manufacturers from 73 locations nationwide.

concreteproductsgroup.com | 800.765.0872
info@concreteproducts-group.com

CBIS Korf’s Hi R Specially designed CMU and individually molded insulation insert. Block and insulation is combined by producer prior to site delivery. Variety of inserts may be grouted and reinforced without removing inserts. Structural units may be used above or below grade.
korf@cbisinc.com | cbisinc.com | 800.628.8476

Product Innovations
A block may be a block, but it is that simple. Thermal properties of a single wythe concrete masonry assembly may be impacted by unit density, configuration and number of webs and face shells and by the presence and placement of insulation or grout. Even small changes in mix design or mold shape can make a great impact on the thermal performance of a CMU. Lightweight aggregate can make a great impact on the thermal performance of a CMU. Lightweight aggregate is an ingredient in CMU that raises R-value. In fact, according to ACI 122R, Guide to Thermal Properties of Concrete and Masonry Systems, the thermal conductivity of concrete with a density of 90 lb/ft³ is less than half that of concrete with a density of 140 lb/ft³.

Revisions in ASTM C90 Standard Specification for Loadbearing Concrete Masonry Units, adopted in 2011, permit, but do not require, webs of concrete masonry units to be configured differently to meet evolving market needs. Knowing that cross webs are thermal bridges, industry professionals sought to decrease thermal bridging by reducing the height/thickness of cross webs. A typical conventional CMU

OneStep Building System Reassembled high performance concrete masonry unit (CMFU) designed by a former mason that allows designers to create an efficient building envelope using single Wythe masonry construction.

OneStep is laid by normal masonry standards creating an architectural and structural wall in 12” or 16” widths that includes finished interior and exterior masonry veneers, a 1” air/weep cavity, a continuous insulation blanket and over 7” of cast in place reinforced concrete mass, once the wall is complete (all in one step). Benefits include energy efficiency, moisture resistance, 4-hour fire rating, endless design options, and a block that is only 35 lb, allowing for higher productivity.

King’s Material onestepbuildingsystem.com | 800.332.5296
steve@onestep-midwest.com

cfiFOAM Like spray polyurethane foam (SPF), Aminoplast foam insulation has two-components. Dry-powder resin and catalyst also extends block life and reduces freight cost. Aminoplast foam is white with a texture like open-cell SPF. Installers don’t wear protective suits and adjacent trades can work uninterrupted while CMU walls are being insulated.
cfiFOAM.com | cffiFOAM Foam Insulation/core-foam

800-656-3626
800-656-3626

Stony Creek Services, injected block fill foam installer, services both new and retrofit construction. Synthetically produced foaming elastomeric plastic is durable with structural integrity and extraordinary fire resistance. One of the safest and most efficient thermal and acoustical insulations available for over 30 years, originally developed for and used in the NASA program, improved over the years through an US Department of Energy grant.

stonycreekservices.com | 586.292.1507
alcornellier@stonycreekservices.com

InsulTech™ Concrete Masonry System from Oldcastle offers high thermal efficiency in an innovative design system. It is 100% thermally broken, providing continuous insulation even in corners. The InsuTech System includes a pre-assembled structural masonry unit available in standard finishes as well as Trenwyth® colors and finishes. Interior face may be a different color and textural finish from exterior face. lenbrowning@oldcastle.com | 844.495.9211
InsuTechSystem.com

ProBlock Open ended A-shaped block with two smaller webs (75° each) reduces thermal bridging. Use of expanded shale, clay and slate lightweight aggregate with about half the density of typical normal weight aggregate contributes to a thermal resistivity 2.5 to 3x as high. These combine for increased R-value and more energy efficient performance overall especially when filled with Aminoplast foam insulation. Modified lightweight A-block is better balanced thus easier for masons to handle, increasing productivity by shortening schedule, reducing costs. May be integrally pigmented with any designer face on either or both exterior and interior faces. Available throughout the US and Canada.

theproblock.com | jerry@theproblock.com

NRG Insulated Block delivers high performance through zero thermal bridging. Architectural finish exterior, continuous EPS insulation and impact resistant interior produce a cost effective high performance building envelope. Over 150 NRG buildings in the last twenty years. Recently, thirty-thousand NRG units helped achieve LEED Platinum in Jersey City Municipal Services Complex. Available in 8”, 10”, 12” and 14”.
nrginsulatedblock.com

Nualero Insulated Block delivers high performance through zero thermal bridging. Architectural finish exterior, continuous EPS insulation and impact resistant interior produce a cost effective high performance building envelope. Over 150 NRG buildings in the last twenty years. Recently, thirty-thousand NRG units helped achieve LEED Platinum in Jersey City Municipal Services Complex. Available in 8”, 10”, 12” and 14”.
nrginsulatedblock.com
has three cross webs. Manufacturers developed CMU with either one cross web (H-Block) or two (A-Block) cross webs rather than three in order to improve thermal performance. These products are referred to as one- or two-web assemblies by NCMA.

**Filling the Cores** Depending on geographic region and seismic requirements, single wythe wall assemblies are either partially or fully grouted. Full grout essentially makes a solid concrete assembly and renders web configuration irrelevant in terms of thermal bridging. Fully grouted walls do, however, maximize a wall's thermal mass properties. More on that in a bit. Partially grouted assemblies may take advantage of filling available cores (those not filled with reinforcing bars and grout) with insulation. Foam filling cores is a process used for years. Empirical and mathematical evidence clearly indicates a CMU wall with foam filled cores does perform better (thermally) than a CMU wall without foam filling. Insulating cores of standard CMU increases thermal performance by insulating air pockets and reducing air flow through the wall.

For reference, NCMA TEK 6:2B, *R-Values and U-Factors of Single Wythe Concrete Masonry Walls*, states that a normal weight 8" (125 to 135pcf) uninsulated wall has an R-value of 1.9. The NCMA Thermal Catalog of Concrete Masonry Assemblies Second Edition (2012) offers tables for expandable foam-filled cores. In the catalog, a conventional 8" block wall, lightly reinforced (48" oc) and varying by block density (125 to 85pcf), will have a range of R-values from R3.65 (U0.274) to as much as an R5.63 (U0.177). In an 8" block two-web assembly (A-shape), lightly reinforced to vary by block density from R4.78 (U0.209) to as much as an R6.85 (U0.146). In the same table, an 8" block hybrid wall composed of two-web (A-shape) and single-web (H-shape) assembly lightly reinforced to vary by block density from an R5.88 (U0.170) to as much as an R7.89 (U0.127). Figure 1 illustrates the effect of unit density and insulation on an 8" CMU wall across the seven climate zones of the IECC for walls exposed on both faces (exterior and interior) and for the interior walls exposed with rigid insulation on the interior. The Ys indicate that code minimums are met by the given single wythe assembly via the prescriptive method. Where code isn't met prescriptively, other compliance paths may be taken.

**Integral Insulation** As manufacturers continued to explore ways of improving the energy efficiency of single wythe wall systems, product design got interesting. In addition to strategies like reducing cross webs, manufacturers varied their approach to reducing thermal bridging by eliminating one crossweb and/or lowering height of the cross web and/or incorporating insulation into the unit design. A new breed of product known as Integral Insulated Concrete Masonry (ICMU) was created.

Manufacturers of these Integral Insulated Concrete Masonry product designs utilize plastics, insulation inserts, etc to reduce or eliminate thermal bridges completely. This separation of mass by insulation or non-conducting materials is the thermal break that gives these integral insulated masonry systems more effectiveness in reducing thermal bridging.

Some products have completely removed or minimized thermal bridges. This has been done by creating a unit with a face shell and structural core divided by a foam insert or with plastic arms that connect two faces. Built course by course, and laid in mortar like traditional CMU, ICMU may vary in composition elements, but ultimately create a single wythe masonry wall system with improved energy efficiency. Sizes and finishes vary by manufacturer, but as with traditional CMU, design flexibility is built in, as is moisture protection, sound isolation, mold and pest resistance, fire safety, durability, low maintenance and all the other added value inherent to masonry.

Because of unique compositions of these units, R-values must be determined through testing; they cannot be or are difficult to calculate. **Table 2** lists the R-value minimum for the insulation only and U-factor maximum of the mass assembly per climate zone required by the 2009 IECC. Most manufacturers list test data on their websites. Check to see whether a particular system meets code prescriptively by comparing its R-value or U-Factor to this table. Call your local representatives to learn more.

**System Performance** As stated before, the prescriptive method of compliance is the least flexible. Each building component must comply separately. The next compliance method, called System Performance (or also known as Trade-offs) considers the overall building envelope, and allows for increasing thermal efficiency in one component (such as more insulation in the roof) with a complementary reduction in thermal efficiency in another component (walls or windows, for example). System performance can be a very helpful method for compliance by providing increased flexibility for designers, and in some cases, can lead to use of building components that would otherwise not comply with prescriptive requirements. System Performance compliance is accomplished through the free computer program COMCheck (available from the Department of Energy at energycodes.gov/comcheck). It is important to note that not all states allow the use of COMCheck for energy compliance, so local requirements should be consulted.

A user-friendly program, data can be selected from dropdown menus or manually-entered if the menu doesn’t have the right system included in the program’s default. The program calculates compliance with the energy code based on the input data and project climate zone. It also states the percentage above or below code, allowing designers to dial projects in when specific goals are in mind. COMCheck has default settings for masonry walls based on loose fill insulation and partial grouting at 32" oc vertically and 48" oc horizontally. By choosing Other (U-factor) option in the drop-down menu, users can enter wall data based on actual insulation and reinforcing spacings. Other Mass Wall option of input is recommended as the specific thermal properties of a given assembly can be input, instead of relying on COMCheck defaults which may not be representative of the actual assembly to be used.

Meeting Energy Codes with Single Wythe Masonry in SMART: **dynamics of masonry** vol 1 no 3 is a case study describing how a single wythe and metal hybrid wall system was designed and evaluated by COMCheck to achieve code, giving the owner the durability and aesthetics of masonry while still achieving an energy compliant building envelope in climate zone 6.

**Whole Building Energy Analysis** Programs like DOE-2 and EnergyPlus are more complicated than simply adding up the R-values of layered materials to reach a total U-factor of the assembly to satisfy the prescriptive method of compliance or entering data into
Getting from R-values to Thermally Efficient Wall Systems

Insulation functions to impede the transfer of heat (conduction) and air movement (convection) through the wall assembly, thereby controlling the interior temperature, amount of heating/cooling required and occupant comfort.

Another piece of the energy efficient wall system puzzle important to masonry is thermal mass – the ability to store heat. Code reflects masonry’s thermal mass in lower minimum R-value requirements for mass walls than other non-mass wall types. For example, prescriptive requirements based on U-factor for Climate Zone 4 are U0.104 for mass walls, but U0.084 for metal buildings, U0.064 for a metal framed building and U0.084 for a wood framed building. Like insulation, this thermal heat storage (and subsequent slow release of heat) can play a significant role in the initial design and cost of a building and subsequent occupant comfort and operational heating costs.

Integrally insulated concrete masonry products elongate the thermal pathway (increasing thermal lag), and combine mass with insulation in a balanced approach. This balance of mass plus insulation that makes a room comfortable and keeps the utility bills low is sometimes referred to as offering an Effective R-Value or Performance R-Value.

Effective R-Value is sometimes considered to be the calculated R-value plus the estimate of the effect thermal mass will have on the energy performance/efficiency of a wall. Variables affecting this performance are great and it is important to note that there is no standardized methodology for calculating the Effective R-value of a wall system. A mass wall with a calculated R-value of 11.4 may perform as though its R-value were much higher, however, Effective R-values CANNOT be used to determine compliance with any requirements in the energy code.

The thermal mass wall's ability to slowly release heat (or cool) back into a space over time tempers outdoor temperature fluctuations and reduces energy draws during peak times, reducing work of the HVAC as well as costs of associated energy. In some climate regions, thermal mass may contribute more to energy performance goals than insulation.

In Sean O'Brien's article, Think Thermal in SMART dynamics of masonry vol 1 no 2, he shares data indicating that lower R-value mass (masonry) walls use the same or less energy as higher R-value lightweight walls.

Preliminary estimates corroborate this for Oakcrest School in VA where the choice of single wythe Integrally Insulated Concrete Masonry contributes to a reduction in HVAC tonnage of 30-50%. Additionally, the smaller HVAC system provides further operational cost savings as it will be easier to maintain and run more efficiently with less cycling.

While more difficult to measure, the thermal performance of a mass wall may be its greatest attribute.

A New Era

Despite limitations of prescriptive tables, cutting-edge design and product innovations have brought about a new era in single wythe design.

Clearly, there are many viable options for modern single wythe masonry design and construction. Any one of these products and systems may be used in a single wythe design of schools, places of worship, single family homes, multi-family residential units, dorms, retail centers, restaurants, theaters, libraries, fire stations or hospitals based upon today's code. The single wythe concrete masonry wall system is found on buildings of all types and in all climate zones. Awareness of the various paths to code compliance arms designers with more options, overriding the limitations of prescriptive design, and to take advantage of the many benefits of various single wythe masonry options.
Ed Weinmann, LEED
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Weinmann has been an independent consultant
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