



L. Robert Kimball
& Associates' LEED
Gold-rated Clearview
Elementary School
(Hanover, Pennsylvania)

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Pushing the Energy Envelope with ICFs

By Vera Novak

Energy consumption may be regulated by code, but it is increasingly driven by client demand. With rising costs of utilities, heightened efficiency goals are surfacing as key design guidelines. Additional parameters of sustainability and protection against natural disasters place even higher requirements on the building envelope's design.¹

One of the technologies that has emerged to meet these market demands in residential and commercial construction is the insulating concrete form (ICF). Combining the thermal qualities of expanded and extruded polystyrene (EPS and XPS) plastic with the strength and durability of concrete is being seen as an economical solution.

Since its development in the 1950s, the formulation of EPS has been refined to enhance product performance while maintaining cost-effectiveness. For example, minimum performance properties for EPS insulation can be referenced by specifying standardized test protocols (such as ASTM International C 578, *Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation*).

Although ICFs were first developed as a below-grade foundation wall forming system, they quickly moved above the surface—it can now be used for interior walls, sound barriers, storm shelters, and structural elements. Plumbing and electrical chases are generally cut into the interior foam face once the concrete has been placed. (While large pipes are not usually designed to be inside exterior walls, they can be fit into the ICF formwork prior to concrete placement.) Electrical conduit can be preset into the concrete for easier access for rewiring, while service penetrations are also generally preset prior to concrete placement, with an acrylonitrile butadiene styrene/polyvinyl chloride (ABS/PVC) pipe.

R-value and energy performance

A seemingly easy parameter for choosing insulation would be to consult the tested R-value of the material.² The term 'R-value' was developed to represent the ability of an insulation material to restrict heat flow. It is tested in accordance with ASTM C 518, *Standard Test Method for Steady-state Heat Flux Measurements and Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus*.

The test specimen usually consists of 0.09 m² (1 sf) of material 25.4-mm (1-in.) thick, whose surfaces have a temperature differential of 0.56 C (1 F). The thermal conductivity (k) of a material is expressed as the rate of heat flow in BTUs per hour, stated as its 'R-factor.' Thus, R-value is the R-factor of an insulation material multiplied by the amount of material used.

However, this is tested in laboratory conditions, which only represents the potential of the material in the center of the cavity, or the 'clear wall value.' It takes into account neither the actual conditions of installation, nor product continuity (as in the 'whole-wall value'). Test data has demonstrated materials with similar R-values do not exhibit the same thermal performance in field applications.³ In the case of ICF construction, three factors enhance the effectiveness of thermal performance beyond the stated clear wall R-value:

- continuity of insulation;
- reduced air infiltration; and
- thermal mass.

In frame construction, the relative lower R-values and the thermal conductivity of the framing membrane must be factored into the clear wall values of the insulation. By comparison, the very nature of the ICF foam as a concrete forming system means complete continuity of the insulation, which then provides a consistent R-value without a thermal break.

The other key factor in improved thermal performance is the typical absolute air barrier provided by the monolithic concrete wall. ICF homes consistently show results of 0.15 air changes per hour (ACH) or less.⁴ Intake vents provide supplementary filtered and conditioned air to meet requirements of the applicable American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) 62, *Ventilation for Acceptable Indoor Air Quality*.

Continuous insulation and reduced air infiltration are key factors for reducing the size of the HVAC equipment. While commercial HVAC modeling software can calculate these parameters for wall assembly components, this has only recently been introduced to residential HVAC contractors. It is solely in the most recent (i.e. eighth) edition of the *Air-conditioning Contractors of America (ACCA) Manual J* that there are allowances for specifying the



The creation of insulating concrete forms (ICFs) involves pouring concrete into expanded or extruded polystyrene (EPS or XPS). The result is a composite building component that can combine concrete's durability and strength with plastic's potential thermal advantages.

Another advantage for buildings constructed with ICFs lies in the material's ability to absorb heat and delay the transfer of this energy to the interior environment. The thermal mass wall acts as a buffer to control indoor temperature fluctuation, reducing peak loads and decreasing HVAC needs.



air leakage of the building envelope. Default values range from 0.45 to 1.05 ach for average construction on heating loads.⁵ Entering the significantly lower ICF values of 0.15 ach can reduce HVAC equipment sizing significantly.

There is yet another element increasing the effectiveness of ICFs as energy-efficient envelopes—the benefit of thermal mass. This refers to the concrete's ability to absorb heat and delay the transfer of this energy to the interior environment. In geographic areas with cool nighttime temperatures, this stored heat is then diffused at night.

The mass wall acts as a buffer that moderates indoor temperature fluctuation, which reduces peak loads and allows for a decrease in the sizing of HVAC equipment. Current residential sizing software does not factor in the savings from thermal mass. In response, the Portland Cement Association (PCA) developed an Excel program that uses DOE-2 software to estimate the required heating and cooling system capacity for single-family concrete homes based on a user-defined thermostat set point, house dimensions, construction materials, and location.⁶

Additional construction opportunities

Code requirements for ICF construction is covered in Chapter 19 ('Concrete') and 26 ('Plastics') of the 2006 *International Building Code (IBC)*, and Section R 611 ('ICF') of the 2006 *International Residential Code (IRC)*. For a tight building envelope, window installation per ASTM E 2112, *Standard Practice for Installation of Exterior Windows, Doors, and Skylights*, and careful detailing of the continuity of insulation at the wall-to-roof connection is recommended. Further, *IRC* requires flashing per Section R703.8 to prevent entry of water to the building structural components.

This 'standard' ICF construction is already a substantial step toward several energy incentive packages. For example, for an Energy Star designation from the U.S. Environmental Protection Agency (EPA) and the Department of Energy (DoE), a home must be 15 percent more energy-efficient than the 2006 *International Energy Conservation Code (IECC)*. The insulative qualities of ICF construction contributes to achieving this designation. Additional specifications of thermally effective windows, efficient lighting and appliances, and the sealing and placement of ductwork in conditioned spaces provide the remaining savings. A new 'Energy Star with Indoor Air Package' program is being developed to take into account water management to prevent moisture-related problems. ICF construction in compliance with the 2006 *IRC* is already in line with many of these requirements.

Additional code requirements apply to minimum construction for governing design wind loads. For example, *IRC* Section 611.8 specifies the wall-to-floor connection, with prescribed size and spacing of anchor bolts for high-wind areas. Some state codes may have stricter measures or provide alternative guidance—the designer should always check with the authority having jurisdiction (AHJ).

Generally, buildings must be designed to withstand a wind speed that has an approximate 500-year return period. While this is not equivalent to the force generated by tornadoes, ICF buildings designed and constructed in accordance with contemporary codes have withstood such events, along with hurricanes.⁷ For additional protective measures, the Institute

for Building and Home Safety (IBHS) has developed the 'Fortified... for Safer Living' program, which specifies construction, design, and landscaping guidelines to increase a home's resistance to natural disasters.⁸ ICF construction already has substantial wind-load capacity and structural integrity, as well as the benefits of fire resistance and reduced water damage to meet the program requirements.

In some states that already have requirements based on the wind tables of American Society of Civil Engineers (ASCE) 7, *Minimum Design Loads for Buildings and Other Structures*, the additional measures necessary to achieve the 'Fortified' designation may be recognized by insurance companies for reductions in insurance premiums.

Federal tax incentives

The *Energy Policy Act of 2005 (EPAc 2005)* established tax incentives for energy efficiency measures on buildings or systems placed in service from January 2006 through December 2007. Legislation is pending that would extend this program.

Under the current bill, a residential builder can receive a \$2000 tax credit for each home with a performance calculated to exceed IECC's heating and cooling use by 50 percent.⁹ The building envelope component improvements must account for at least one-fifth of this 50 percent. Houses built with ICF exterior walls have been found to require an average of 44 percent less energy to heat and 32 percent less energy to cool than comparable frame houses—well within the parameters of the *EPAc 2005* bill requirements.¹⁰

For residential projects, the homeowners are directly eligible for credits on renewable energy sources, such as photovoltaic (PV), wind, or geothermal technology. With the energy needs of a home greatly reduced by ICF walls, the remaining energy requirements are smaller, making renewable packages more economically feasible.

Both the Energy Star designation and the tax credit criteria must be verified by a third party, using EPA-approved software based on DOE-2. Qualified raters can be found through the Residential

Energy Services Network (RESNET), which has accredited rating programs in all 50 states and more than 2000 raters certified across the country.¹¹

EPAc 2005 also offers businesses a deduction of \$1.80 per 0.09 m² (1 sf) for commercial buildings that achieve a 50-percent reduction in annual energy, compared to ASHRAE/ Illuminating Engineering Society of North America (IESNA) 90.1-2001, *Energy-efficient Design of New Buildings Except Low-rise Residential Buildings*. Since the energy load of a building is extremely dependent on the nature of the application (e.g. cooling for occupant ventilation in a school versus cooling for manufacturing equipment), partial deductions of \$0.60 per 1 sf are available for improvements to the building envelope, lighting, or heating/cooling system that reduce total energy consumption by one-third the 50 percent goal.

ICF points to LEED

A review of the 69 possible points within the U.S. Green Building Council's (USGBC's) Leadership in Energy and Environmental Design for New Construction (LEED-NC) identifies energy savings as the most heavily weighted criteria, with up to 10 points achievable for buildings designed for energy savings over requirements set in the benchmark ASHRAE/IESNA 90.1.

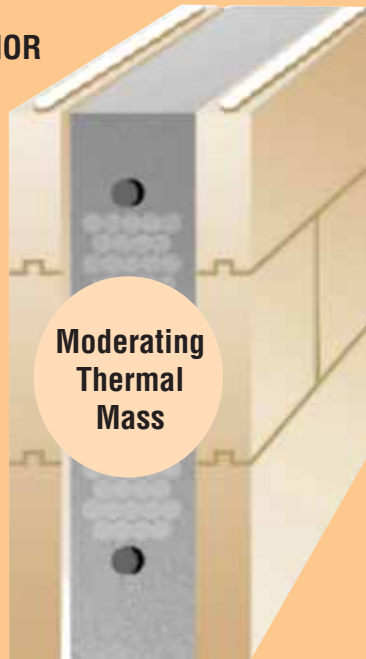
This strong focus on energy savings is appropriate considering the bulk of a building's environmental footprint is caused by the natural resource consumption for utilities over the structure's life. The high-performance thermal envelope of ICF construction can offer a significant contribution towards achieving all 10 of the points available within Energy & Atmosphere (EA) Credit 1, *Optimize Energy Performance*. While these are some of the most difficult to achieve, two LEED Gold projects using ICFs have already earned all 10—Clearview Elementary School (Hanover, Pennsylvania) and the Pennsylvania Department of Environmental Protection in Cambria. A third ICF LEED project, Xanterra Yellowstone National Park, has earned seven of them.

Photo courtesy RESNET



**Fluctuating
Outdoor
Temperature**

EXTERIOR



INTERIOR

**Controlled Moderate
Indoor Temperature**

The photo at left depicts the blower door test used to gauge the effectiveness of a thermally efficient system. For more on blower doors, see the article on structural insulated panels (SIPs) on page 6. The diagram at right explains the basic properties of an ICF wall.



Homes that reap the benefits of energy-efficient wall systems, such as those created with ICFs, can also earn developers and building owners tax incentives under the *Energy Policy Act of 2005 (EPAct 2005)*.

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Additional potential point categories include:

- Sustainable Sites (SS) Credit 5, *Reduced Site Disturbance*;
- Materials and Resources (MR) Credit 2, *Construction Waste Management*;
- MR Credit 4, *Recycled Content*;
- MR Credit 5, *Local/Regional Materials*;
- Indoor Environmental Quality (EQ) Credit 2, *Increased Ventilation Effectiveness*;
- EQ Credit 3, *Construction IAQ Management Plan* ;
- EQ Credit 4, *Low-emitting Materials*; and
- EQ 7, *Thermal Comfort*.

The ICF package

Often the best solutions are the simplest ones, with multifaceted characteristics meeting a wide range of expectations. The same straightforward construction techniques apply to both residential ICF dwellings and high-rise commercial projects. ICF construction can not only easily conform to structural requirements set by code, but can also offer energy savings, safety, and sound insulation.¹²

The durability of both the plastic EPS and the concrete shell can help lengthen the life of the ICF envelope. Increasing incorporation into U.S. and Canadian codes would indicate the continued growth of this construction technology. ☺

Notes

¹ For more on the possible roles of plastics and natural disasters, see “SPF Beyond Energy Insulation” by Mason Knowles on page 17.

² As plastic formulations can vary by manufacturers, design professionals should consult their suppliers’ specification sheets to understand the chosen product’s exact properties.

³ See the Portland Cement Association (PCA) SN 2518, *Energy Use of Single-family Houses with Various Exterior Walls*, by John Gajda, CTL. For more on whole-wall studies, see “Plastics Takes Improvement to the Wall: New NAHB Research Center Wall Study About Heat Flow—

R-value not the whole story,” by Craig Drumheller, in the June 2006 issue of *Modern Materials*. Additionally, as insulation formulation may vary from manufacturer to manufacturer, design professionals should consult the suppliers’ specification sheets to understand the exact properties over time, including the actual R-values. The higher the R-value, the greater the insulating power.

⁴ See PCA CD 025, *Energy in Thermal Mass Walls*.

⁵ See Section 8 Infiltration Loads, Table 5A in the *Manual J*. For more information, visit www.acca.org/tech/manualj.

⁶ The DOE-2 software was developed by James J. Hirsch & Associates in collaboration with Lawrence Berkeley National Laboratory (LBNL), mostly under funding from the Department of Energy (DoE). For more information, visit www.DOE-2.com. Also, see *HVAC Sizing Methodology for Insulated Concrete Homes*, by the U. S. Department of Housing and Urban Development (HUD) Office of Policy Development and Research. Visit www.toolbase.org/PDF/DesignGuides/HVACSizingMethodology.pdf.

⁷ See “Solutions for Natural Disasters—Using concrete and plastic insulation for safety and energy efficiency in residential design,” by Cecile Mutton, PEng., in the November 2004 issue of *Modern Materials*.

⁸ Visit www.ibhs.org.

⁹ Credits can be claimed using Internal Revenue Service (IRS) Form 8908. For more information on HR6, Federal Tax Incentives for Building Energy Efficiency, visit www.energytaxincentives.org. See also Jared Blum’s article, “Plastics and the 2005 Energy Policy Act,” in the June 2006 issue of *Modern Materials*.

¹⁰ Access the Concrete Homes Technology Brief 1 by visiting www.cement.org/homes/brief01.asp.

¹¹ Visit www.resnet.us.

¹² For more on the benefits of ICFs, visit the Insulating Concrete Form Association (ICFA) Web site at www.forms.org.

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