E3 Design Group & Building Sciences

PERSPECTIVES

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ICF Walls in Residential Construction in Hot and Humid Climates

Abstract

The housing market has slowed to its lowest level in more than 20 years and the surviving builders are working to differentiate themselves by incorporating "new" ideas into their projects. As energy costs continue to rise, there has been renewed interest in high performance energy efficient building envelopes that cost less to own, operate and maintain. E3 Building Sciences has tested more than 1600 residential homes with a variety of wall systems: Wood frame, masonry block, SIP and ICF walls. This issue of PERSPECTIVES will look at ICF construction in the residential marketplace from a cost and performance perspective.

♦ Background

A building "envelope" is made up of many components: the foundation, floors, walls, windows, doors, and a roof. The overall envelope serves as a thermal, moisture and air barrier between the outside environment and the inside. The envelope can also act as a "filter" to make the indoors more comfortable by allowing air, heat, coolness, and humidity to migrate across the building envelope. A "tight" envelope works as a barrier to limit uncontrolled airflows either from outside to in (infiltration) or from inside to out (exfiltration). A tight envelope makes a significant contribution to the overall efficiency of the building. However, even with a high quality tight envelope the building shell will lose heat in cold weather and gain heat during the summer. To minimize these losses / gains we need to address four specific issues:

(1) *Reduce Heat transfer by minimizing the transfer of heat / cold through the material(s) of the building envelope by conduction and convection.* The laws of thermodynamics state that heat always flows from hot to cold. All materials conduct heat – some materials are very efficient at conducting heat and others are very effective insulators – the higher the R-value the better the insulator.

(2) *Stop infiltration* and prevent the leakage of outside air(infiltration) and the escape of conditioned air (exfiltration) in and out of the building envelope.

(3) *Control sunlight* and the associated radiant heat energy gains by the use of heat reflective glass. The Solar Heat Gain Coefficient (SHGC) is a measure of the reflective ability of some glazing to reject heat. A high performance window for a semi tropical climate will typically have an SGHC <0.40.

(4) *Control humidity*—Humidity plays a crucial role in perceived comfort. In semi-tropical climates like south Florida, the control of humidity is the primary task of the HVAC system. However, the dehumidification (latent) capacity of most HVAC systems is limited to about 30% of the overall rated cooling capacity. Often during off-peak hours the sensible cooling requirement is minimal while the latent load soars. Stand-alone dehumidification systems interconnected with the HVAC systems are the best way to regulate humidity independent of air temperature.

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♦ Introduction

The vast majority of homes built in this country are of wood frame construction in part, because wood has traditionally been a locally available resource that is easily worked with hand tools and does not require highly skilled labor. In areas where wood was scarce, other wall systems emerged. Adobe structures more than 1500 years old are still standing in the Southwest. However, masonry construction (brick or CMU) typically requires more skill and is slower to construct than a comparable wood frame wall. CMU / block construction is significantly more pest resistant than wood and is well suited to areas subject to high wind loads because, typically, CMU / block walls are a stronger wall system than (conventional) wood framing.

"ICF" is a variation of masonry construction which consists of hollow preformed polystyrene blocks that are stacked into the shape of the exterior walls. The sides of the block are interconnected with plastic ties that may also serve as support for rebar within the wall cavities. Some products have imbedded furring strips for the attachment of interior and exterior surface finishes. ICF forms have been around for more than 30 years and are often derisively referred as "Lego" block construction.

Most of the ICF block systems provide an interlocking connection system that allows the builder to simply stack them on an appropriate foundation and then pour reinforced concrete into the interior hollow creating a strong and well insulated concrete wall. They can (in the hands of the right crew) reduce construction time while utilizing less skilled labor. Properly executed, an ICF wall will be straighter, plumber and stronger than a comparable wood frame wall. They can offer superior thermal performance, significant sound attenuation, durability and pest resistance and ease of construction when compared to most other wall systems.

The majority of ICF buildings in North America have been single family homes. However, commercial, institutional and industrial buildings have all been built using ICF walls. ICF construction is growing and some architects are pushing the boundaries of ICF design. Manufacturers of ICF wall systems are responding with new and innovative solutions that significantly enhance the capabilities of the ICF wall system.

♦ Construction Costs

Normally, we would attempt to deconstruct a project and compare the costs of a wood frame home to a home using CMU masonry walls versus the same plan with ICF walls. Unfortunately, it is extremely difficult to complete a price analysis of one wall system versus another as the material prices for lumber, concrete and oil are and have been extremely volatile over the last 18 months.

Wood frame construction is the preferred wall system in most of this country. Wood frame costs in Florida have been traditionally higher than other parts of the country due in part to the lack of local softwoods and the high cost of transporting finished lumber. Until April of 2006, Softwood lumber prices in the U.S. were artificially high in part due to heavy tariffs imposed on Canadian softwood lumber imports. New residential construction consumes about 50% of all the softwoods harvested in North America. A typical 2500 SF wood frame home uses roughly 20,000 board feet of dimensioned lumber and another 7500 square feet of structural panel wood products (roof trusses, plywood, OSB and MDF). Framing lumber prices have declined as much as 40% since April of 2006 and competition in our marketplace has driven *the cost of wood frame walls to between $8.50 to $11.00 / SF.*

Wind, pest resistance and impact resistance makes CMU masonry walls the most common type of construction in South Florida. Concrete prices have climbed significantly since 2006 to more than $105 / cubic yard from less than $65 / cubic yard. *CMU masonry walls are between $10.50 and $13.00 SF.*

Finally for comparison, ICF masonry walls cost between $11.70 and 14.50 / SF depending on the ICF block manufacturer and the market price of concrete. One of the reasons for the disparity in cost when compared to CMU walls is that the ICF blocks are large and, although light weight, are expensive to ship from factories in northern climates. Some manufacturers are addressing this issue by making the blocks collapsible and with innovative packing designed to reduce shipping costs.

However, on any given day, lumber prices can spike and concrete prices can sag. The worldwide demand for wood and concrete has risen sharply due to strong global demand and a weak U.S. dollar.

Events in the Middle East have caused a sharp rise in the cost of oil –significant in the cost of transporting all construction materials and that the underlying raw materials (polystyrene) used in ICF forms is made from hydrocarbons. Accordingly, any attempt to "deconstruct" the cost of building with a comprehensive pricing analysis of one material versus another would be outdated before it was finished. Accordingly, we turned to ICF manufacturers, material distributors and contractors to get some anecdotal evidence of the costs. E3 BUILDING SCIENCES spoke with several ICF manufacturers and general contractors currently building homes utilizing ICF wall systems, and the consensus of opinion was surprisingly similar:

Wood frame walls at $9.75/SF x 2600SF ≈ $23,350.—
CMU masonry walls at $12.35/SF x2600SF ≈ $32,110.—
ICF block wall costs @ $13.50/SF x2600SF ≈ $35,110.—

The cost differential between a masonry block and an ICF wall is ≈ $2,990.—, *slightly less than 10 percent more when compared to CMU block construction.* However, the cost of the walls in a residential project makes up a relatively small portion of the *overall* construction budget. Assuming a cost of $155 / SF for the house as a whole, the cost of the walls ($35,110 / $387,500) represents less than 10% of the overall budget. Assuming the balance of this project uses the same materials and methods of construction, use of an ICF wall system added approximately $1.20/SF to the cost of construction *which represents less than 1% of the overall cost*. If we assume an interest rate of 6.5% over the life of a 30 year mortgage the incremental cost of the ICF wall is less than $19 per month.

From a cost perspective, does ICF construction offer savings elsewhere to offset the initial higher costs of construction and are there other "less tangible" benefits associated with ICF construction?

♦ ICF FROM A BUILDING SCIENCES PERSPECTIVE

A recent study in Atlanta (published January 2007) conducted by the local utility compared the costs to heat and cool two comparable homes. Located within a mile of each other, one of the houses was carefully built with a sealed attic with a measured CFM(50) of .31 CFM per square foot and the other was also carefully built using conventional CBS construction with a vented attic. The measured CFM(50) was 1.1 CFM per square foot (which based on our testing is a very "good" infiltration number). After 12 months of monitoring, *the tighter ICF house averaged a 38% reduction* in energy usage for heating and cooling. The monthly average heating and cooling costs were about $110 / month in the "conventional" and $68 / month in the super-insulated "tight" house. If we ignore the savings required to heat the house in winter, and apply the FP&L rate of 12 cents / kWh the resulting savings is about $28 month (which more than offsets the $18 per month mortgage premium for ICF construction). Now if you factor in inflation and assume that energy costs will rise with inflation (2.5%) then you can assume that the ICF house will result in a savings of more than $7,500 over the 30 year life of the mortgage.

An ICF wall is significantly more insulated (R=24) than a typical CBS block wall (R=4.1). However, the average temperature difference across an exterior wall in Florida is relatively small – about 18 degrees in the summer and winter. Accordingly adding extra wall insulation (above R=4.1) results in only about a 10% reduction in overall heat gain. The differential temperature (ΔT) provides the driving force for the heat "migrating" from the warm outside to the cooler inside. So while a 10% overall reduction in heat gain is a good start, *wall insulation in Florida is less important than other factors affecting the overall efficiency of the building envelope.* The solar performance of the windows (particularly in homes with floor to glass ratios > 20%) has the greatest single effect on overall heating and cooling loads.

Several factors contribute to the thermal efficiency of an ICF wall. (1) There is no thermal bridging that is characteristic of both wood frame and masonry walls; (2) The comparatively high thermal mass of the wall minimizes interior temperature fluctuations; and (3) the polystyrene forms typically have a superior R value when compared to other forms of insulation such as Fi-Foil seen in masonry wall construction and batt insulation typical of wood frame construction. How significant is "thermal mass"? The importance of thermal mass is the subject of great debate among building scientists. ICF walls characteristics are consistent with other high mass wall systems in that they adsorb heat (or cool) and they have a noticeable ther-

mal lag. It turns out that this thermal lag is more significant in cooling climates. In studies conducted by the US / Department of Energy (Office of Building Technology) at the Oak Ridge National Laboratories showed that in a climate that is dominated by cooling, high mass walls can save as much as 18% of overall HVAC energy costs when compared to low mass walls of an *equivalent* R-value.

Based on our experience designing residential HVAC systems in both masonry and ICF homes, we believe that conventional split-DX HVAC systems can be downsized as much as 20% in an ICF home. While some of this difference may be attributed to the greater thermal mass of an ICF wall, a significant portion of the savings is likely attributable to a reduction in infiltration. We prefer to proactively filter, refresh, cool (or heat) and dehumidify the air within the building envelope to address IAQ issues, than to have to have to deal with uncontrolled air infiltration that can result from more conventional construction and the associated infiltration loads.

ICF construction is significantly stronger than block. The resulting cement "matrix" within an ICF wall is at least twice as strong as conventional block construction. Many people believe that block wall construction is a "safe" hurricane wall. Block walls are susceptible to hurricane related missile impacts and can be breached by flying debris. Some CMU masonry contractors address this by pouring every cell in the block wall with concrete. This practice adds more than 10% to the overall cost of the wall and still does not result in a wall system as strong as an ICF wall. While a "poured solid" block wall is (relatively) strong, the inherent "woven" design of a block wall precludes the optimum placement of reinforcing steel when compared to a comparable ICF block wall. Further, CMU walls that are poured "solid" create significant thermal bridging that requires more than the code minimum R=4 insulation to insure reasonable "energy" performance in our climate.

Virtually all of the ICF homes we have tested utilize sealed attic construction; typically using an open cell spray foam insulation applied directly to the underside of the roof deck. This construction method coupled with ICF walls yields a house that approaches air tight. This can lead to poor indoor air quality (IAQ). However, we are of the opinion that it is better to build as tight an envelope as possible, and address IAQ issues by introducing controlled amounts for fresh air that has been conditioned or heated and humidified or dehumidified.

The tight house that results from ICF construction also results in a very quiet house (especially when paired with high performance windows) that is almost dust free. For more than five years we have recommended sealed attic construction to clients with environmental sensitivities. Further, sealed attic construction adds significantly to the life span of the air handler. Typically, based on our experience, the HVAC system can be "downsized" commensurate with the approximate 20% reduction in heating and cooling loads that result from this type of construction. Accordingly, a 2500 SF home built with a sealed attic will have an HVAC system that costs ≈ $1,500 less than conventional vented attic construction. After having tested a significant number of ICF homes with sealed attic construction we have found that the CFM(50) infiltration rate is less than 0.25 CFM per square foot of floor area. For comparison purposes, a typical CMU block house with a vented attic has a CFM(50) of about 1.2 CFM per square foot. For equivalent homes, this equates to a 79% reduction in infiltration and can result in significantly lower HVAC operating costs.

♦ CONCLUSIONS

ICF construction has the potential to offer energy savings and can deliver a significantly more durable building shell when compared to a wood frame home – albeit at a slightly higher price. When compared to a CMU shell, ICF walls are stronger and offer superior thermal performance.

It is our opinion that the additional cost associated with ICF construction is insignificant in the context of the overall cost of the building envelope and that the additional costs will be easily offset by the energy savings seen in ICF wall construction.

However, as the majority of the homes we tested utilized a sealed attic along with ICF construction, the actual amount of the energy savings attributable to the ICF wall system is hard to quantify. We have anecdotal evidence that suggests that savings are in the range of 18 to 30%. ICF homes have the potential to be constructed more quickly by less skilled labor than an equivalent CMU or wood frame home.

♦FAQ's

Does an ICF wall system house require special house plans?

Almost any home can utilize ICF construction with little or no alterations to the plans.

If ICF construction is better than conventional construction methods, why don't I hear more about it more often and why isn't everybody requesting it?

The construction industry is slow in adopting new technologies. The inertia of the marketplace favors existing methods and materials. Further, until recently, the cost of building with ICF's was significantly higher than conventional construction. Now that costs are approaching parity, ICF homes are likely to capture significantly more market share. Given their pest resistance and durability, resale values of ICF homes may be higher than a conventional CMU or wood frame home in the future.

Will an ICF home be more susceptible to fire?

The majority of ICF blocks are constructed of expanded polystyrene with an encapsulated borate. Borate is a well recognized flame retardant and renders the polystyrene highly fire resistant. As a result, the polystyrene must be exposed to an external flame source and if it does catch on fire, it emits less toxins than burning pine lumber.

Does the Insurance Industry recognize ICF as a legitimate building material and are there discounts afforded homeowner's of ICF homes?

Yes. Most insurance companies will offer significant discounts for ICF construction. The Florida Office of Insurance Regulation mandates certain discounts and requires homes meeting certain structural guidelines to be offered the lowest available wind premium. We would suggest contacting your insurance agent prior to purchase.

Are ICF homes more susceptible to mold?

No! Mold is ubiquitious in a hot and humid climate. However, by building a tight house and controlling the infiltration and interior humidity your home will be mold free. Maintaining a relative humidity below 50% will insure that mold growth cannot occur. In wood frame homes, the insulation can trap moisture in the wall cavity and promote the growth of some molds. An ICF wall limits potential mold growth.