National Association of Home Builders

Research report:

Insulating Concrete Form Systems (ICFs)

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The NAHB Research Center is a wholly-owned subsidiary of NAHB

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Insulating Concrete Form Systems (ICFs)--In-Depth Analysis

Summary

Insulating concrete forms (ICFs) are rigid plastic foam forms that are filled with reinforced concrete to create structural walls. They hold concrete in place during curing and remain in place afterwards to provide thermal insulation. ICFs are used to make structural concrete walls, and can be used to make either foundation or above-grade walls. The forms are typically made from pure foam-plastic insulation but may also be made from a composite of cement and foam insulation or a composite of cement and processed wood. The foam is typically either expanded polystyrene (EPS) or extruded polystyrene (XPS) and occasionally polyurethane. Forms come in three basic form-types: blocks, planks, and panels. Blocks are molded, hollow foam blocks that are stacked, much like Legos ™;. Plank and panel types use flat sheets (typically) of foam held together with plastic or metal ties, with panels using larger sheets of foam, similar to metal or plywood formwork. The resulting shape of the concrete, explained in more detail later, will be one of several shapes: flat, waffle- or screen-grid, or post-and-beam.

As with any product, ICFs have their advantages and disadvantages. Although they can be more expensive than other residential wall types, and there is much debate over their use below grade because of termites, ICFs appeal to builders and homeowners due to the many possible advantages of ICFs. Advantages over conventional construction include a reduction in the number of trade contractors required, strength, thermal efficiency, reduction in through-the-wall sound transmission, and the ease of construction. This report presents these issues and more in further detail, including comments from builders and homeowners familiar with ICFs.

The use of ICFs in the United States appears to be growing. The Portland Cement Association (PCA) reports that in 1994, 0.1% of all new homes used ICFs in above-grade walls (about 1100 new homes). That number rose to 0.2% in 1995 and 0.7% in 1996. The PCA reports that, based on ICF shipment data and a National Association of Home Builders (NAHB) survey, the number of houses built using ICFs increased to 10,344 in 1997, compared to 7,336 in 1996.

There are currently more than 35 manufacturers of ICF systems. Many manufacturers belong to the Insulating Concrete Form Association (ICFA), an industry trade group.

Details

ICF Types

There are many ICF wall types. Products are differentiated based on the type of form and the shape of the concrete. Products are further differentiated by how forms attach to each other, how finishes are attached to the wall, insulating values, foam types and other features. Introductory information on the most basic products types follows. Check the Resources listed for more detailed information. The book, *Insulating Concrete Forms for Residential Design and Construction* includes an in-depth discussion of the options and issues.

Form Types

As mentioned above, ICFs come in one of three basic form types which are differentiated by the size of the form units and the way they connect to one another.

> *Panel* systems are the largest units, available in sizes from approximately 1'-3" x 8'-9" up to 4' x 12' resembling traditional plywood forms in size and shape. Panel systems allow a large section of wall area to be erected in one step, but may require more cutting in the field. The panels have flat sides and are connected to one another with metal or plastic ties. They can be shipped flat.
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> *Plank* systems consist of long, narrow planks of foam held together at a constant distance apart by metal or plastic ties. Planks may have notched, cut, or drilled edges that the ties fit into. Plank-shaped forms range in height from 8 to 12 inches and are either 4 or 8 feet long. Plank systems differ from block systems in that they can be shipped flat, either because the ties can bend or because the ties are inserted as the wall is constructed.
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> *Block* systems resemble hollowed-out concrete masonry units (CMU) in size and shape, although the dimensions may vary from the typical CMU. Block systems include units ranging from standard concrete block size (8-inches high x 16-inches long) to a much larger 16-inches high x 48-inches long. Their edges interlock without separate fasteners, using a rabbeted edge, tongue-and-groove configuration, mortise and tenon-type configuration, or similar. Blocks arrive on-site, ready to stack with their ties, made of the form material itself, metal, or plastic imbedded in the form.

Concrete Shape Types

ICFs are further differentiated based on the shape of the concrete once poured into the forms. Four distinct cavity shapes are possible: flat, waffle-grid, screen-grid, and post and beam. Figure 1 shows several shape types.

Flat ICF Wall Systems have a solid concrete wall of constant thickness, just like a conventional poured wall formed with plywood or metal forms. They typically have a nominal concrete thickness of 4, 6, 8, 10 or 12 inches (actual thickness of the concrete can range ½ inch plus or minus the nominal thickness).

Waffle-Grid ICF Wall Systems have a solid concrete wall of varying thickness and, as the name implies, look like a breakfast waffle. These systems have a nominal concrete thickness of 6 or 8 inches for horizontal and vertical concrete cores. Maximum spacing of vertical cores is typically 12 inches on center and maximum spacing of horizontal cores is typically 16 inches on center. The webs in between the cores usually have a minimum thickness of 2 inches.

Screen-Grid ICF Wall Systems have a perforated concrete wall of varying thickness, similar to the waffle-type systems but with solid form material (foam, foam-cement composite, etc.) between the horizontal and vertical members instead of concrete. These systems have a nominal concrete thickness of 6 inches for the horizontal and vertical that creates a concrete screen instead of a concrete waffleconcrete members. Maximum spacing of vertical cores and horizontal cores is defined as 12-inches on center in the *Prescriptive Method for Insulating Concrete Forms in Residential Construction* (*Prescriptive Method*). See the Code/Regulatory section for more information on the *Prescriptive Method*.
Post-and-Beam ICF Wall Systems are similar to the screen-grid systems in that vertical members (columns) and horizontal members (beams) are formed. However, the spacing between them is wider, up to four feet for columns and between four and eight feet for beams.

Figure 1: Most common ICF concrete shapes.

Click to view larger image

Form and Shape Combinations

The combination of form and shape types result in many possible configurations. For example, a panel system could be designed to produce either a flat shape or a waffle-grid concrete shape. Or, a block system could be used to produce a screen-grid or waffle-grid concrete shape. See Table 1 for possible combinations of form and shape types currently available in the U.S. and Canada.

Table 1. Available ICF Combinations				
		Form Type		
		Panel	**Plank**	**Block**
Shape Type	**Flat**	X	X	X
	Grid	X		X
	Post and Beam	X		X

Other System Attributes

Fastening Options. Some forms come with built-in fastening surfaces for attaching drywall, trim or other finishes. Others require attachment of finishes through the insulating form to the concrete itself or to furring strips.

Corner Details. There are several different types of ICF corners. If pre-formed corners are not available, two standard forms can be miter-cut and glued together to form the corner piece. Each ICF manufacturer has specific recommendations for the corner assembly of their product.

Special Options. Various manufacturers may offer one or more of the following specialty features/options: brick ledge blocks, lintel blocks, hinge corner blocks, foam stops, rebar hangers. See *Insulating Concrete Forms for Residential Design and Construction* for a comprehensive discussion of products by manufacturer.

Foam Types

ICF forms may be made from pure foams or cement composites. Pure foams can be expanded polystyrene (EPS), extruded polystyrene (XPS), polyurethane or polyisocyanurate. Most systems use EPS. XPS is available only in flat board shapes and is, therefore, not used in any block-type forms or other shaped, molded forms such as for the grid systems. Polyisocyanurate is rarely used. Cement composites may be a combination of foam and cement (always EPS) or wood and cement. Foams are rated on their thermal properties, density, strength, and resistance to wind and moisture. Foam density can have a significant impact on the physical characteristics of the foam, especially thermal insulation (R-value), strength, and moisture retention.

EPS and XPS are both made from polystyrene but the manufacturing process is different. EPS, the type of foam used for disposable coffee cups, begins as small plastic "beads" that are expanded and then fused together. XPS begins as a molten material that is pressed out of a form in a continuous process to form sheets. Polyurethanes are made from a mixture of two ingredients: an isocyanate, a polyol, and a blowing agent. Cement-foam composites are a mixture of Portland cement and EPS beads.

EPS is resistant to air infiltration, moderately strong, and usually the least expensive foam. EPS foams have R-values that range from 4.0 to 4.2 per inch when dry, based on respective densities of 1.35 to 1.8 pounds per cubic foot[1] for Type II and Type IX foam, respectively. Type II foam, with an R-value of 4 per inch, is most commonly used in ICFs. EPS can be molded to form blocks or panels for grid or post-and-beam systems or cut into sheets for flat panel systems. It is not as resistant to moisture as XPS. Long-term exposure to moist, below-ground conditions in freezing climates will degrade foam R-value. For this reason EPS, especially, should have moisture protection when used below grade as its R-value may be reduced to 2.4 per inch under more severe conditions. According to the *Building Foundation Design Handbook*, EPS in ground contact is best suited for application in well-drained situations. Table 2 displays R-values for foam exposed to these conditions. Manufacturers literature should be consulted for verification. The insulating value of ICFs in above-grade walls should not be expected to diminish. Consult ASTM Manual MNL 18, *Moisture Control in Buildings-Chapter 4: Effects of Moisture on the Thermal Performance of Insulating Materials*, for more information on this subject.

XPS foam (Type IV, V, VI, VII) has an R-value of 5 per inch when dry (4.5 per inch with long-term exposure to moist, below-ground conditions in freezing climates), regardless of density. Like EPS, XPS is resistant to air infiltration, but stronger. It is ordinarily available in sheet form only and is more expensive than EPS.

Table 2: R-values for foam exposed to moist, below-ground conditions in cold climates from the *Design Guide for Frost Protected Shallow Foundations*.

Foam Type	R-Value (per inch)
Type II EPS	2.4
Type IX EPS	3.2
Types IV, V, VI, and VII XPS	4.5

Cement composites have an R-value of 3 per inch when dry, with a density of 21 pounds per cubic foot. All the composite form types contain cement and, therefore, tend to be stronger than any of the foam-only form types. They are also heavier and are more difficult to cut, but potentially more durable than foam forms.

Choosing a Product

There are some significant differences among types and brands of ICFs. Therefore, builders should carefully consider all options and associated advantages and disadvantages before committing to building with ICFs or using any particular type or brand of ICF. Particular advantages and disadvantages of ICFs versus other common wall types are discussed in detail in the Benefits and Limitations sections.

When deciding on any particular type or brand of ICF, some of the factors to consider include:

- Availability
- Price
- Ease of use
- Unit size
- Strength: building, wind, soil, other loads
- Fastening surfaces for finishes, amount of bracing required during construction
- Concrete amount/cost required to fill forms (amount of concrete needed can range from .0005 to .35 cubic yard per square foot)
- R-value
- Dimensional consistency
- Manufacturer support: technical and marketing
- Code approval (Evaluation Reports and local approval)
- Foam type

- Form type: flat wall, waffle-grid, screen-grid, post and beam
- Specialty units/devices: corners, rebar hangers, brick ledges
- Field assembly required

For specific information on these items it is necessary to contact manufacturers directly and to also talk with others who have used them. The Resources section has contacts for associations that have information on manufacturer and supplier members and may also supply information on builders or projects that use ICFs.

Installation

Basic Construction Steps

Below is a typical construction sequence for building walls with ICFs. For the most part, these steps apply to both above and below grade. **Note that many details are not included and that exact procedures or sequence may vary according to type, manufacturer, code requirements, and/or preference. Check with the manufacturer to determine specific construction details.**

Basic Construction Steps: Walls

- Place dowels (rebar) in footings, foundation wall, or slab as required.
- Place temporary or permanent braces along first course to prevent sideways movement if specified by ICF manufacturer.
- Place first course flush with braces. Blocks can be set in "green" concrete footings. (See Figure 2)
- Possibly place termite shield if required by code authority.
- Complete one course all the way around. It will likely be necessary to cut block or panel per wall segment.
- Set horizontal and vertical rebar as required. (See Figure 3)
- Subsequent courses should typically be staggered so that vertical joints do not line up from one course to the next if specified by manufacturer. Make sure vertical and horizontal cavities line up.
- Cut for openings as required (or cut out after entire wall is built)
- Install bucks/opening blockouts. (See Figures 4 through 7) A buck may be one of three types: recessed, protruding, or "channel." A pressure-treated 2x buck is frequently installed to provide an attachment surface for windows and doors. Alternatively, a water-resistant membrane may be used between wood and ICFs. Some prefabricated plastic and vinyl bucks are now available and becoming widely used. Sizing a buck is key to efficient installation of windows and doors. Whether the windows have "masonry style" window frames or frames with nailing flanges, the rough opening should be sized appropriately to accommodate the actual windows size.
- Brace forms as required. (See Figures 8 and 9) Strong, temporary bracing of all walls and openings in ICF walls is important to keep them plumb and square during the concrete pour and to support the weight of the concrete until it achieves the desired strength. Bracing is needed at corners, window, and door openings, periodically along the length of walls, and at the top of the forms. Top braces square the forms and provide a surface to check wall height and cut uneven blocks.
- Place anchor bolts and ledgers as required. (See Figure 10) Floor system attachment options include ledger, pocket, embedded joist hangers, or direct bearing. Ledgers may either be pressure treated wood or may include a water-resistant membrane. Consider where the ledger will line up with the form so it coincides with anchor bolt placement. Bolts and ledger are placed before pour, with foam cutouts around bolts to allow concrete to back up ledger (ledger face must not "bear" only on foam). Embedded joists require cutting out the foam and inserting wood spacers before the pour to create a pocket in which to seat the joist. Some code authorities also require the embedded joist to be fire-cut.

- Sleeve penetrations.

- Foam seal joints as required (possibly as you go per course)
  Foam sealant can be used along joints to secure blocks until concrete is poured. This is especially handy during windy conditions. Excessive sealant (gluing horizontal and vertical seams) will make it difficult to plumb the forms prior to pouring the concrete. Some ICF systems have interlocking edges to reduce or eliminate the need for gluing. Sealant, if used along the horizontal and vertical seams, will reduce cold spots at the joints where joints are not interlocking.

- Cut holes in bucks as needed to pour concrete (may be done before installation of bucks).

- Pour concrete in 2 to 4 foot lifts using chute or pump per manufacturer's instructions. (See Figure 11) A "high flow" concrete mix that will move well through a 2-inch pump is typically used. A free-flowing mix is paramount to allow concrete to flow into all interior spaces of the form. Failure to follow manufacturer's instructions for bracing and lift can result in a blow-out. If a blow-out occurs, it can then be quickly repaired. Blow-out kits are typically constructed with lumber or plywood and some form of attachment/bracing.

Construction Tips from the Field

Following are some tips regarding construction that were gleaned from the NAHB Research Center's *ICF Demonstration Homes Project.*

- By following manufacturer's installation instructions and using reasonable care, concrete wall blow-out problems can be easily avoided.

- A practical mix of ICFs and wood or metal framing can be used to solve special structural problems.

- Wood for temporary bracing is an expense that can be minimized through the use of metal bracing that can reused more often.

- The added cost of pre-formed or pre-packaged corners and rebar saddles is justified by time savings on the jobsite.

- Concrete must be placed into ICFs at a slower, more controlled rate than conventional forms. Some skill, preparation, and practice are necessary to get good results. Proper consistency is needed to avoid voids or honeycombing that can weaken walls and increase the potential for water leakage. Unintentional voids created in post-and-beam and screen-grid systems are of particular concern due to the voids already inherent in these types of systems. Follow manufacturer's recommended guildelines for selection of the proper hose size and type. A 2-inch diameter hose and 2 "S" couplings are generally recommended.

- Use a flexible hose for concrete pumping. A rigid supply pipe with a reducer may be prone to clogging during the pour.

- Straighten forms at the last minute, just before concrete is poured.

- Consider purchasing or renting a portable concrete pumping truck. This may be especially useful in remote areas.

- If adapting a wood-framed design, remember that ICF walls are thicker and the overall dimensions of the design should be increased to create the same size interior space. Remember the wall thickness when hanging doors and windows. For example, an inward opening door will not open if it is flush to the exterior wall surface; and an out-swinging door will not open if it is installed flush to the interior of the wall. Windows can be set at any depth in the ICF wall. Windows are recommended to be mounted with the exterior face creating deep interior window sills. However, this is dependent on the type of exterior finish selected.

- Extension jambs, hand trimming, or special drywall detailing may be needed on inside of window and doors because of the ICF wall thickness. This may require extra work from the installer or finish carpenter. (See Figure 12)
- There are certain features of ICFs that will likely necessitate changes in current construction practice for a number of trades. These changes range from the necessity to use special water barrier materials below grade in place of commonly used petroleum-based products (see Figure 13) to the change in practice or additional steps necessary to attach drywall or cabinets. A list of these items and others in a not-necessarily-complete list of related items follows, with further discussion of some items.

Changes in Current Practice Likely with the Use of ICFs

The use of ICFs may require changes in current practices throughout the construction process. Changes include (details follow):

- Attachment of finishes, trim, cabinets, and interior partition walls: Finishes may require special attachment methods.
- Moisture protection: Products used for moisture protection of foam below-grade must be non-petroleum based.
- Utility penetrations: Through-the-wall penetrations require pre-planning and sleeving, or later drilling through concrete. (See Figure 14)
- Installing wiring and plumbing in walls - Foam must be grooved out for pipes and wires.
- HVAC equipment may be sized smaller than that for conventional residnetial construction; however, determining how much less may be difficult.

Attachment of finishes (See Figures 15 through 18)

Some systems use plastic ties or have built-in fastening strips that allow direct attachment of siding, drywall and other finishes to the forms, using screws. Other forms require attaching wood or metal furring strips to the concrete, after which finishes, trim, and cabinets can be installed normally. Sometimes the spacing of the ties is not congruent with the siding material, in which case furring strips need to be attached to the ties for siding attachment. One builder reported that his drywall contractor charges more because doesn't like having to "glue and screw" rather than nail and screw. Another builder said that on future ICF houses he will consider attaching 2 x 4 furring strips spaced 30 inches on center to the interior side of the forms to allow shallow electrical boxes to be attached and to speed drywall installation.

Due to the weight of cabinets, it is not sufficient to attach them to the form ties or attachment strips. Plywood or some form of wood furring can be attached to green concrete and then used to hang cabinetry. Metal angles can be placed around the interior perimeter to screw in trim. Electrical boxes and similar items may also require special attachment methods, although they may be attached to furring if available. In some cases, receptacle boxes, pipe straps, and other utility-related hardware may require direct attachment to the concrete.

A related problem is the possibility of bulges occurring in the wall resulting from inadequate bracing during the pour. In this case it is necessary for someone to shave or rasp the surface of the foam to provide a flat surface for finishes, etc.

Problems have occurred when connecting interior walls with ICF walls. Several ICF manufacturers provide suggested methods for securely fastening interior walls to the exterior ICF wall. Possible options include use of masonry or concrete nails, or powder-actuated fasteners. Another possible option is not securing interior partitions walls to ICF walls at all, but solely to ceilings and floors, possibly with the addition of horizontal blocking between the stud next to the ICF wall and the adjacent stud to impart some stiffness.

A Virginia Beach, VA builder found that careful planning for locations of interior frame wall connections during ICF system installation can eliminate any lost time or extra cost later during the interior wall construction process.

Moisture protection

The need for moisture protection of foam below-grade is similar to that required on other types of below-grade walls. Cast-in-place and block foundation walls are typically either waterproofed or dampproofed with a petroleum-based product. However, petroleum-based products cause deterioration of foam and cannot be used with ICFs constructed of XPS, EPS, or polyurethane. ICF and sealant manufacturer representatives, literature, and specifications should be consulted to determine compatible materials and installation methods.

Penetrations

Location of utility penetrations for ICF construction should be determined in advance to the degree possible. It is generally recommended to sleeve penetrations with PVC pipe before the concrete is poured and install the utilities later. Consult with the trades that will need penetrations and keep records that show the desired size and location of each. Some users of the waffle-grid wall systems prefer to hammer-drill through the 2-inch thick web for penetrations less than 1-1/2 inches in diameter. This choice depends upon the type of system used, builder requirements, and trade preference. In screen-grid and post-and-beam systems, especially, it may be possible to put penetrations through solid form material and avoid penetrating the concrete altogether.

Large penetrations, such as for vent stacks or ductwork, may need an engineer’s structural analysis, especially if significant concrete is displaced by the chase. Alternatively, large penetrations can be placed in interior walls or be framed out. Temporary bracing during the pour may also be required if too much foam is cut away. Avoid placing ducts and plumbing in exterior walls, where possible.

Installing wiring and plumbing in walls

In order to run wires and accommodate electrical boxes in ICF walls, grooves can be cut into the foam using a hot-knife or router. Some contractors have said they actually find this easier than drilling holes in studs. For electrical boxes, recesses can be cut to the exact depth required. Pipes and wires are sometimes fastened to the concrete using plastic or metal ties and concrete nails. Cutting foam will reduce the wall's thermal integrity. Therefore, groove depth should be minimized and tape or spray-foam should be placed over any cut out sections. Necessary protection of wires and pipes should also be considered.

Larger pipes, in particular, may require deeper grooves. In one known case, a plumber had to chip away excess concrete for 2" vent and drain lines on the exterior walls since interior furring was not used. Although pre-planning would allow the plumber (or someone) to make a "space" or a "recess" for such vents and eliminate the need for expensive concrete chipping, this plumber chooses this method since it eliminated an extra site visit.

HVAC sizing

Mechanical contractors may experience some difficulty determining expected peak heating and cooling loads because of ICFs higher R-values and lower infiltration rates. Also influencing sizing is the possible effect of thermal mass as there may be an associated time lag for heat transfer that affects peak load timing. Unfortunately, oversizing of equipment occurs often, so more efficient buildings may see even greater oversizing. Oversizing leads to reduced equipment efficiency, occupant comfort, and, possibly, shortened equipment lifespan. Field testing can determine air infiltration rates and help with proper HVAC sizing.

Benefits/Costs

ICFs may be used for either above- or below-grade walls. The comparative benefits and limitations of ICFs must be considered in light of the systems which it replaces. In the United States, foundation walls are typically cast-in-place (CIP) concrete or CMU (block) walls, whether for basements, crawlspaces, or stem walls. For above-grade walls, the predominant construction is some variation of wood-framing. The discussion below uses these typical construction types as the point of comparison.

Benefits: Foundation Walls

ICFs can be used for full basements, crawlspaces, or stem walls for slabs. Possible benefits of ICFs when compared to block (CMU) or cast-in-place (CIP) concrete foundations include:

- Protection of concrete from temperature extremes -- Insulating forms make it easier to protect the concrete from freezing and rapid drying. Concrete can be poured in ICFs down to 10°F, requiring only the top of the form to be protected with insulating blankets. In extremely hot weather, in which evaporation is a concern, the top of the form need only be covered with plastic sheeting.
- Foundation walls built with ICFs may be easier and faster to construct than either CMU or CIP foundations depending on the area.
- With ICFs, forms do not need to be removed as with normal CIP concrete using wood or metal forms, eliminating another visit by installation crews to revisit the site to remove forms.
- Especially where finished basements are desired, the cost differential may be quite small.
- ICF walls are ready for interior finishing although some products may requiring furring out first.
- Carpentry crews can be trained to build with ICFs quite easily. Studies have shown that the learning is overcome during the first three hours of building with ICFs.
- Labor and, possibly, total labor plus material costs may be less than CMU foundations.
- When used as a stem wall for slabs, ICFs provide built-in slab edge insulation for enhanced energy efficiency because the interior slab is poured completely inside the exterior ICF wall. ICFs provide an easier method for placing edge insulation than conventional methods.
- Scheduling of trades can be simplified because specialty foundation construction-related trades may not be needed.

Benefits: Above-Grade Walls

ICFs can be used in place of wood framing for most above-grade situations, placed on slabs or basement or crawlspace walls. Possible benefits of ICFs over wood framing include:

- Strength, namely resistance to high winds

- Energy efficiency / Comfort
- Thermal Mass
- Noise abatement
- Durability
- Reduced number of subcontractors and construction steps
- Extension of the building season

Strength - Wind Resistance

The walls of a properly-constructed ICF home are exceptionally resistant to loads imposed by high winds. ICF walls will resist penetrating forces such as flying debris during high winds better than wood-framed walls, as shown in a PCA video.[2] In both coastal hurricane areas and other high wind areas, where building codes require an analysis of wind resistance, typical ICF wall systems exceed current code requirements. It should be noted that in both conventional wood frame and ICF construction, the roof connection and construction and protection of windows are often most critical in avoiding wind damage, as are appropriate anchors to the footings and foundation.

Strength - Seismic Resistance

ICF structures can be designed for all seismic zones. The industry is only now starting to consider shear wall testing of ICF wall systems. Shear wall testing is needed to quantify the methods of compliance of ICF home designs in earthquake-prone areas.

Appearance

From the outside, ICF homes look similar to wood framed homes since a number of finishes such as EIFS and vinyl siding can be used. Homeowners may like the thick walls that provide deep interior window sills for use as window seats or window display areas, similar to the effect of adobe construction.

Energy Efficiency

ICF walls provide higher R-values (between R-18 and R-35)[3] and lower air infiltration rates than typical wood frame construction (typically R-12 to R-20). However, wood frame construction can be built to have comparable R-values and air infiltration rates for an additional cost that would not likely exceed the cost premium typical of ICFs. ICFs also provide higher R-values than typical concrete or block foundation wall construction, perhaps with similar air infiltration rates. Concrete and block foundations can be insulated after construction to reach R-values equivalent to ICFs, but perhaps not as affordably and with some additional time and difficulty.

Thermographic testing by the NAHB Research Center, Inc. of an ICF home showed that a solid ICF wall (clear wall with no windows or penetrations) had fewer cold spots than a similar wood-framed wall. However, selection and installation of many other elements of a house, such as windows, ceiling insulation levels, air sealing methods, and HVAC equipment, all have an impact on the overall energy efficiency of the house. The use of an airtight wall system such as ICFs does not automatically eliminate leakage through or around windows. Infiltration reduction is most effective with systematic air sealing of the entire house. Testing of leakage rates and thermographic testing has revealed the importance of sealing air leakage paths in all components of the exterior envelope.

A recent study, *Energy Comparisons of Concrete Homes versus Wood Frame Homes*[4] has quantified energy savings that are possible with ICFs. In this study, the energy use of 26 pairs of similar houses in the same climates were compared. An average energy savings of 44% (range: 36-53%) for space heating and 32% (range: 15-48%) for space cooling was found. Average combined heating and cooling energy savings was 42% (range: 34-50%) and combined heating and cooling cost savings averaged 21% (range: 17-25%). Annual cost savings (based on actual local fuel costs) averaged $250 (range: $201 - 298). Projected savings for a 2,000 square foot house in Minneapolis was $376.

Percentage energy savings for ICFs compared to wood frame varied little by climate. (Based on the savings reported in this study, a rough simple payback analysis was conducted by *Energy Design Update* magazine and found to range from five years for an "optimistic" projection to 16 years for a more conservative, but not extreme, estimate). In the study, energy consumption was adjusted to account for differences in house size, design, foundation type, number of occupants, thermostat settings, and HVAC equipment. Construction specifications (insulation levels, air sealing techniques, etc.) were not provided for the framed houses.

When combined in a wall system with concrete, steel, and framing around openings, an R-value unique to the particular manufacturer's wall system results. This R-value can be measured directly or can be calculated. Typical Clear Wall R-values range from R-13.5 to R- 22.5 for major manufacturers ICF products. Table 3 presents R-values of some typical materials used in wood frame and ICF construction.

Table 3. TYPICAL R-VALUES OF MATERIALS

Material, thickness	R-value per inch of material	R-value for given Thickness
EPS foam, 4 inches*	3.8-4.2	15.2
XPS foam, 4 inches	5.0	20.0
Polyisocyanurate foam, 4 inches	~7.0	~28.0
Fiberglass insulation, 3.5 inches	3.71	13.0
Plywood, 1/2 inch	1.25	0.62
Wood studs, 3.5 inches	1.23	4.30
Double pane, vinyl window ("2826")	NA	2.17
Drywall, 1/2 inch	0.90	0.45
Concrete, 8 inches	0.0625	0.50

* varies with density

When considering reported R-values by manufacturers, it is important to understand how those values were determined and whether they are "thermal-mass adjusted R-value." This adjusted R-value is generally what most ICF manufacturers report. For most situations, thermal mass, especially when encased in foam, may not have any measurable effect on actual thermal performance. The use of foam may in fact cause a negative effect on thermal lag, actually adding to peak and total HVAC loads.

Thermal Mass

Concrete has a high thermal mass--the ability to store heat and release it at a later time. In climates with large daily temperature swings, the mass effect of concrete walls can have a favorable impact on energy use and comfort. The presence of the foam can, however, decrease or eliminate the advantages of high thermal mass as the heat absorption and re-radiation is delayed (because of the thermal resistance of the foam) to the point that the mass effect is negated.

Noise Abatement

Research shows that for solid walls, ICFs are much better at reducing lower-frequency noise than wood frame walls. However, the addition of windows quickly diminishes the overall sound performance of a wall assembly. When combined with careful selection and installation of other building elements such as windows, doors, and roofs, ICF construction can provide excellent sound attenuation.

Durability

Foams and concrete hold the potential for improved building durability over wood construction because they are more resistant to moisture and less attractive to termites and other pests. Although foam is subject to moisture retention problems, ICF walls are more rot-resistant and durable than wood-framed walls.

Reduced Number of Construction Steps

With ICF construction, builders can use their framing crews to install a foundation which eliminates the need for a foundation contractor. ICFs also eliminate the need for additional wall insulation or an infiltration barrier.

Extension of the Building Season

Contractors can pour concrete in very cold conditions because the insulated forms keep heat in. Many builders reported that the limiting factor in pouring concrete for ICF construction was that you couldn't get a concrete truck to deliver at extreme temperatures.

COSTS: Above-Grade Walls

Above-grade ICF walls cost more to build than typical wood framed walls. As wood-framed walls approach the thermal insulation value of ICFs, cost differential decreases. In most cases, materials costs (concrete and forms) are primarily responsible for increased costs, while labor costs are often similar to wood framing. Cost premium depends on relative material prices, labor efficiency for each system, necessity for engineering, and effect on other practices or trades, among other factors. The cost premium for ICF houses is smaller in areas such as high-wind regions that require additional labor, time, and materials for special construction of wood-framed houses.

Cost differential can be expressed several ways, either per square foot of wall area, per square foot of floor area, or as a percentage of the total cost of the house to the builder or buyer.

According to an NAHB Research Center study, costs are estimated to increase by 1 to 8 percent of total house cost[5] over a wood-framed house.

A Kentucky builder who uses ICFs for above- and below-grade construction mentions that the industry standard estimate of ICF wall price versus stick built construction is a five percent increase in sales price and that, in his experience, this is accurate.

Results from the NAHB Research Center's *Demonstration Homes Project* showed that total costs for construction of ICF foundation walls can be less than that for block walls. One ICF system had total costs of $1.25 per square foot of house floor area compared to $1.27 per square foot of house floor area for the block wall based on the construction of a short (~ two-foot) "stem wall."

Typical figures for cost differential using above-grade ICFs are listed in Tables 4 and 5.

Table 4. Reported Ranges of Cost Differential between ICFs and Wood Frame for Above-Grade Walls

	Builder Cost	Buyer Cost
Per square foot of wall area	$1.00 - $4.00+	NA
Per square foot of floor area	$0.75 - $4.00+	NA
% of total house cost	up to 8% in one study	1% - 5+ %

Table 5. Cost Summary
NAHB Research Center Demonstration Homes Project

Location	Total Extra Cost ICF Forms	% Increase in Final Sales Price
Virginia Beach, VA	$12,177	4.7%
Austin, TX	$18,843	5.3%
Sioux City, IA	$ 1,505	1.0%
Chestertown, MD	$ 2,049	2.2%

Table 6 shows costs for a one-story demonstration home with an ICF footing and floating slab. Gross wall area equaled 1191 square feet and the floor area measured 1008 square feet. The home is a ranch style with three bedrooms, two baths and vinyl siding.

Table 6. Chestertown, MD Demonstration House: Typical Wood-Framed Construction

Component	Material
Internal vapor barrier	none
Framing	2x4, 16" o.c.
Cavity insulation	R-13
Exterior sheathing	7/16" OSB
Exterior insulation	none
Exterior air barrier	yes

Table 7. Chestertown, MD

Demonstration House:	
ICF Wall Construction Costs	
ICF material	$2,091
Concrete	$898
Misc. materials	$142
Installation	$983
Total	$4,114
Wood-Framed Wall Construction	
Framing Costs	
Material	$722
Installation	$843
Total	$1,565
Energy Features Costs	
Material	$396
Installation	$104
Total	$500
Total Wall Cost	
Material	$1,118
Installation	$947
Total	$2,065

Based on the cost analysis from Table 7, the builder receives substantial premium for ICF construction. Most of the premium can be attributed to the relatively high cost of ICF material. In fact, the ICF materials alone cost 190% more than wood frame materials for the same house. The premium for ICF material costs vary. For example, the ICFs used in the Iowa demonstration cost only 26% more than wood.

Table 8. Demonstration Houses Normalized Wall Costs

Location	Construction Type	Installed Cost per Floor Area (ft2)	Installed Cost per Wall Area (ft2)
Chestertown, MD	ICF Construction	$4.08	$3.45
Chestertown, MD	Wood-Framed	$2.05	$1.73
Sioux City, IA	ICF Construction	$2.79	$3.13
Sioux City, IA	Wood-Framed	$2.20	$2.47
Austin, TX	ICF Construction	$7.79	$5.94
Austin, TX	Wood-Framed	$2.95	$2.25
Virginia Beach, VA	ICF Construction	$6.46	$6.65

Virginia Beach, VA	Wood-Framed	$2.08	$2.14

COSTS: Foundations

For foundations, ICFs cost about the same or less than CMU or cast-in-place wall systems. A builder in Fairbanks, AK uses ICFs for basements and crawlspaces. ICFs cost him about the same as for block construction with furring and insulation, but can be erected in one-third of the time.

COSTS: Potential Added Costs for ICF Construction

- Engineering: The builder of the Virginia Beach Demonstration House reported a slight cost increase for engineering services. The builder is a structural engineer and normally does his own engineering but he had an outside structural engineer involved with this particular home.
- Because of the thick walls that ICFs produce, finishing doors and windows may add expense. Doors and windows will require extension jambs, hand trimming, or drywall returns. The use of drywall returns may be more cost effective than hand trimming.
- Trade contractors (siding, drywall, plumbing, electric, carpentry) may charge extra because of unusual tasks such as routing in foam for wires or pipes, installing furring strips for siding installation, screwing vinyl siding in place, or using adhesives and screws for hanging drywall. On the Chestertown, MD demonstration house, most of the trades did not charge more for working on an ICF home. The framer charged more, but the increase was offset by not requiring other trades. The electrician charged 5% to 6% more.

COSTS: Offsets to Additional Costs

Builder Costs

Because ICF construction is inherently energy efficient and airtight, heating and cooling equipment and ductwork can be downsized, resulting in a lower cost for equipment.

Siding costs can be reduced when Exterior Insulation and Finish Systems (EIFS) are used for the exterior finish since the foam used for these finish systems is already in place.

One builder from the NAHB Research Center *Demonstration Homes Project* reported a decrease in customer service costs due to fewer callbacks.

When basements are intended to be finished, there would be some cost reduction from minimizing or eliminating insulation and interior framing along exterior walls.

Costs for Homeowners

Because ICFs are well-insulated and airtight, homeowners will have lower operational costs (utility bills) than a typical wood-framed house.

ICF homeowners' insurance may be given a concrete structures discount. One builder reports that a ten percent reduction is typical.

COSTS: Methods for Cutting Costs

Process Improvements:

Centex Homes of Dallas is currently experimenting with construction of ICF wall sections off-site, much like panelized of wood framed walls. Initial results indicate that they can reduce cycle-time by 30 to 40 percent with panelization. Centex expects that ICF houses will sell for $3 per square foot of floor area more than their wood-framed houses.

Waste / Material Cost Reduction

Materials are a significant portion of the relatively high cost of ICF construction and the amount of waste materials appears to be a direct function of the installer's knowledge of ICF construction. One Virginia Beach, VA builder subcontracted out his first ICF home and found there was considerable material waste. Now, he uses his own employees for installation, and there is less material waste (currently estimated to be 4%) and 20% lower labor costs.

Costs: Learning Curve Impact

Builders should expect to see higher costs than expected for the first few houses. As with any new product or technique, there is a learning curve in order to reach typical efficiency and cost. For ICFs, three or four jobs appears to be a sufficient number to overcome the learning curve. Once the process is understood, ICF wall construction typically takes about the same time as wood-framed wall construction. The learning curve can apply to others involved in construction, from engineers and architects to builders, trade contractors, and code officials. Additional time is needed for background research as builders decide upon system type, manufacturer, best methods of construction such as methods for providing attachment for trim, and choose compatible components such as waterproofing and finish materials.

Endnotes:

1. PCA Wind Tunnel Tests

2. VanderWerf, Peiter, *Insulating Concrete Forms*

3. VanderWerf, Pieter

4. NAHB Research Center, Inc., *Demonstration Homes Project*

Limitations

ICFs may be used for either above- or below-grade walls. The comparative benefits and limitations of ICFs must be considered in light of the systems which it might replace. In the United states, foundation walls are typically cast-in-place (CIP) concrete or CMU (block) walls, whether for basements, crawls spaces, or stem walls. For above-grade walls, the predominant construction is some variation of wood-framing. The discussion below uses these typical construction types as the point of comparison.

Limitations: Foundations

ICFs can be used for full basements, crawlspaces, or as stem walls for slabs. Possible limitations of ICFs when compared to block (CMU) or cast-in-place (CIP) concrete foundations include:

- If building codes prohibit the use of foam below-grade, alternative methods must be chosen or the foam form removed after the concrete cures.
- Construction costs may be higher.
- For those entering the business, initial investment for ICFs is cheaper than traditional forms, but life cycle cost of ICFs versus traditional forms may be higher because ICFs are not reusable.
- Because EPS allows termite trails to exist undetected, a gap in the polystyrne may be required to facilitate detection. Some regional codes merely require termite shields; sometimes at the footing and transition from ICF to frame construction junction.

Limitations: Above-Grade Walls

Possible limitations of ICFs when compared to wood framing include:

- Higher total cost.
- Additional engineering in homes not meeting the application limits of the *Prescriptive Methods*
- Difficulty gaining code acceptance, although the *Prescriptive Method* and IRC 2000 inclusive of prescriptive methods should alleviate this issue over time.
- Possible significant time needed to research various products and manufacturers
- Overcoming the training/learning curve
- Difficulty of making alterations such as accommodating larger windows, either during original construction or remodeling.
- Impact on design. Because ICF walls are heavier than wood-framed walls, design changes may be necessary to ensure an ICF wall is placed directly over another load-bearing ICF wall. If the design cannot be changed, wood framing can be combined with ICF construction.
- Thickness of walls impact overall dimensions, door and window installation, and use of extension jambs.
- Impact on scheduling. The need to ship forms (pending establishment of broader distribution network) may require longer lead-time.

Code/Regulatory

Code Adoption Status and the Prescriptive Method

In May of 1998, the NAHB Research Center completed work on the *Prescriptive Method For Insulating Concrete Forms In Residential Construction* (Prescriptive Method) which was funded by the Department of Housing and Urban Development (HUD), the Portland Cement Association (PCA), and the National Association of Home Builders (NAHB). Where approved, builders will be able to follow this prescriptive approach to ICF design and, therefore, eliminate the need for engineering in most houses.

The *Prescriptive Method* includes definitions, limitations of applicability, below-grade and above-grade wall design tables, lintel tables, construction details, various construction and thermal guidelines, and other related information for home builders, building code officials, and design professionals. A prescriptive approach to ICF design eliminates the need for engineering in most applications (See Table of Applicability Limits -- Table 10). The provisions of this document were developed using accepted engineering practices and practical construction techniques; however, users of the document should verify its compliance with local code requirements. The *Prescriptive Method* includes provisions for majority of ICF systems including flat (panel and plank) systems and grid systems (waffle and screen). The *Prescriptive Method* also includes a commentary that provides supporting information, calculations and engineering assumptions. The Prescriptive Method also provides an example which illustrates the correct application of the standards and specifications.

In May of 1998, the *Prescriptive Method* was accepted for inclusion in the International Residential Code (IRC) and the Standard Building Code (SBC). The IRC is scheduled for completion in 2000, and includes provisions for the use of ICFs in both above- and below-grade applications. The 1999 SBC will include requirements and provisions for above- and below-grade residential ICF construction using both flat and grid type forms. Bear in mind that these are model codes and that states or localities must adopt these codes and also have the option to add or remove requirements as they see fit. There is also a fairly typical time lag of three years from the publishing date of the model codes and acceptance by localities.

Structural Design of ICFs Covered by Prescriptive Method

In some cases, especially where the *Prescriptive Method* is not yet accepted, when certain ICF types not covered by the *Prescriptive Method* are used, or when buildings do not meet the applicability limits of the *Prescriptive Method*, engineered designs (usually with sealed sets of plans) may be necessary in order to obtain building permits. Although extensive efforts were made to provide prescriptive requirements applicable all types of ICFs, some systems are not covered. For systems and applications that are not covered by the prescriptive requirements in the *Prescriptive Method*, the NAHB Research Center, under sponsorship of the PCA, completed the publication entitled *Structural Design of Insulating Concrete Form Walls in Residential Construction*. This publication, available from PCA, is a guideline for the design of single- and multi-unit residential structures using ICF wall systems. It includes step-by-step design procedures for ICF, a comprehensive design example, and many design aids, such as graphs, charts, and tables, to assist design professionals for flat and grid systems.

Most ICF manufacturers have taken steps of their own to have their proprietary systems approved by various model code organizations. Engineering reports, or Evaluation Reports produced for/by the code bodies, are available from those manufacturers. Most ICF manufacturers will provide design services if necessary.

Table 10. Applicability Limits for the ICF Prescriptive Method

ATTRIBUTE	MAXIMUM LIMITATION
GENERAL	
Maximum Building Plan Dimension	60 feet (18 m)
Number of Stories	2 stories above grade plus a basement
Story Height	10 feet (3 m)
Design Wind Speed	110 mph (177 km/hr) fastest-mile wind speed
Ground Snow Load	70 psf (3.4 kPa)
Seismic Zone	0, 1, and 2
FOUNDATIONS	
Unbalanced Backfill Height	9 feet (2.7 m)
Equivalent Fluid Density of Soil	60 pcf (960 kg/m3)
Presumptive Soil Bearing Value	2,000 psf (96 kPa)
WALLS	
Unit Weight of Concrete	150 pcf (23.6 kN/m3)
Load-Bearing Wall Height	10 feet (3 m)
FLOORS	
Floor Dead Load	15 psf (0.72 kPa)
First-Floor Live Load	40 psf (1.9 kPa)
Second-Floor Live Load (sleeping rooms)	30 psf (1.4 kPa)
Floor Clear Span (unsupported)	32 feet (9.8 m)
ROOFS	
Roof Slope	12:12
Roof and Ceiling Dead Load	15 psf (0.72 kPa)
Roof Live Load (ground snow load)	70 psf (3.4 kPa)
Attic Live Load	20 psf (0.96 kPa)
Roof Clear Span (unsupported)	40 feet (12 m)

Model Code or Local Code Issues/Barriers

Potential issues or barriers to use of ICFs may be encountered. Among these include the following items which discussed with in more detail below:

- General unfamiliarity of code officials and inspectors with the product
- Fire issues due to the use of foam
- Termites and the use of foam below-grade
- Structural concerns, especially for high loads due to backfilling, wind, earthquake; special constructions; attachment/integration of walls, floors, roofs; and proper filling of forms with concrete
- Moisture protection
- Attachment of finishes

General Unfamiliarity with Product -- Builder Experiences

A builder in Iowa has experienced problems with code acceptance of ICFs in the past. For example, after using the product for three years, his local building department required that the unfinished basement walls be drywalled and taped. After complying with this fire-related requirement, the electrical inspector determined that there were an insufficient number of receptacles in the "finished" basement. The problem was resolved. However, problems like these can occur until inspectors are familiar with the product.

Another builder in Florida mentions that they have problems periodically with acceptance of ICFs by local code officials. Whenever they go to build in a new municipality, one in which ICFs have not been used previously, he has to educate the code officials. His company does this by presenting a video, manufacturer installation manuals, information on acceptance in other areas, and structural calculations performed by the manufacturer’s structural engineer. If the code official is unfamiliar with ICFs, they will hear, "Huh? What is that? You can't build out of foam!" and, "Why are you putting all that steel in there?" When these questions are addressed in a clear concise manner in terms the code officials can understand, acceptance typically follows.

Fire-related Codes Provisions

While building separation, protection, and flammability requirements of building codes vary between jurisdictions and the different model codes, there is typically a requirement that foam in the interior of a house (or other building) be covered with a minimum 15-minute fire-rated assembly to prevent smoke development or combustion. For houses using ICFs in normally unfinished areas such as basements and habitable attics, this would typically require placing drywall or another 15-minute fire-rated material over the foam.

Building officials have expressed some concern about how floor joists are integrated with ICFs. The *Prescriptive Method* should be consulted for details of floor construction with ICFs.

Foams used in construction contain additives that retard combustion in order to meet surface burning requirements of many codes. ICFs are treated so they will not support combustion. Tests show that the flame-spread rating for foams is better than for most wood products.

Termite Protection

Termite protection is a growing issue with ICF construction below-grade in areas of heavy termite infestation. One major concern is the use of foam below grade because it provides a hidden pathway for termites into a structure. Commonly used termite barriers such as soil treatment and termite shields have reportedly been defeated in some cases. Some model code organizations have acted to limit the use of foam below grade in at least some areas particularly susceptible to termite infestation, namely the southern U.S. However, termite infestations can and do occur in areas not normally considered prone to such infestations. This issue is potentially of concern even if all exterior walls are made of ICFs. Termites have been known to travel great distances within a structure to reach wood. This could mean wood used for window or door bucks, interior walls, roof systems, furring strips and the like are all susceptible to attack.

The 1997 Edition of the Standard Building Code (SBC), developed and maintained by Southern Building Code Congress International (SBCCI), prohibits the use of foam insulation below grade and within six inches above grade in heavily-termite infested areas. Even in areas determined to have heavy termite infestations, some ICF houses built on top of slabs and most conventional CIP concrete or block walls used for crawlspace and basement walls should not be affected by this code requirement. The 1998 CABO code also prohibits the use of foam insulation below grade in areas prone to termite attack.

Even in the absence of code requirements, at least one manufacturer, and common sense, indicates that, in areas prone to termites, ICFs should not be used below-grade until effective solutions are determined.

The ICF industry reports that it is currently working to assess the extent of the problem and address it by evaluating solutions. The Insulating Concrete Forms Association (ICFA) recommends, and codes often require, that traditional termite control methods be used for any new construction.

Some foam is treated with boron to resist termite boring but this does not prevent them from traveling behind the foam. Chemical barriers are not always completely effective either as termites may enter the structure below the chemical barrier. The use of pressure treated wood, which is less attractive to termites, for blocking, furring, bucks, etc. may be advisable although use of typically wet pressure treated wood can bring its own problems of excessive shrinking and warping.

A somewhat experimental, but apparently effective, method of termite protection is the use of uniformly-sized, course-grained sand barriers. It appears that the individual grains are too large for termites to push out of the way but the inter-grain spaces are too small for them to get through. This method has reportedly been used successfully in Australia and Hawaii and some builders have used it in Texas and California.

Homeowners and builders may also find that pest control operators will not provide a warranty for houses with foam below grade (essentially refusing to treat). They may also experience difficulty in obtaining loans and possibly insurance as well especially if a treater will not provide a warranty (from greenbuilding@crest.org: "I'm building in NW Arkansas, considered . . . a heavy termite infestation area. I was all set and thrilled to use . . . ICFs in the construction of the slab of my new house but when I tried to get exterminators to give me a bid, . . . they wouldn't touch it").

Another possible solution that some mention is to use one of the wood-cement composite forms. However, this approach may not prove effective as it is not the foam per-se that is the problem, but rather the presence of a hidden pathway into the structure. The use of PVC plastic, metal, cement board or any other material against the foundation would provide the same sort of pathway.

Feedback

Using and Marketing ICFs

Builder's Perspective

Builders look at building with ICFs for a variety of reasons in addition to meeting customer demand for a strong, durable, quiet and energy efficient home. Builders may simply want to set themselves apart from the competition. They may wish to eliminate the need for an experienced mason, reduce reliance on lumber and its associated price volatility, or, in some cases, build foundations less expensively.

An Austin, TX builder states that factors that influenced him to use ICF construction were market/product differentiation, energy efficiency, product durability, and a lack of quality lumber.

A Florida builder started using ICFs four years ago after seeing the effects of hurricane Andrew, combined with a 100% rise in the cost of lumber, He researched several alternatives to wood framing including ICFs, lightweight concrete block, steel, pre-cast concrete, and hay bale, but decided on ICFs due to their strength, price stability, energy efficiency, and availability. One strength-related concern in his area is resistance to flying debris that will penetrate the walls of a wood framed house, but not reinforced concrete. He decided against steel framing because there was a nine-week delivery period. He chose ICFs over pre-cast concrete because of the energy efficiency benefit. He also looked at spray foam for use in wood framed walls but found that option to be relatively expensive without the added strength benefit.

One Iowa builder uses ICF construction to minimize production delays and provide "flexibility for scheduling." He reported masons are among the hardest to get on site. ICF construction eliminates scheduling problems since masons are not needed to build the basement walls. He has found that ICF construction also eliminates concerns with ground water seeping into the basement, a prevalent problem he experienced with block walls.

A builder in Cincinnati says that he could pour practically all winter given the ability of ICFs to extend the lower temperature limit. But, personally he doesn't pour when the temperature goes below 10 degrees Fahrenheit because freezing people aren't productive and, additionally, he’s found that his concrete supplier won't bring concrete to the site in extreme temperatures. Above 20 degrees Fahrenheit, he "doesn’t even give pouring a second thought."

One builder from Chestertown, MD, who has built 47 ICF homes prefers ICFs over wood frame construction for several reasons. He feel that ICFs provide smoother scheduling on his jobs because they do not require as many trades or steps to complete exterior walls. Steps eliminated include installing cavity insulation, exterior sheathing, and house wrap. His continued use of ICF construction is prompted by his concern for energy efficiency and ultimate affordability. He builds in an economically-depressed area and reasons that if customers have trouble with a house payment they will also have trouble paying utility bills. He intends to use ICFs for his next home because of increased energy efficiency and the overall quietness of the home.

A builder from Austin, TX said that, after having built two houses with ICFs, he prefers the finished product of ICF construction to the finished product of wood-frame construction because he feels it is the best house money can buy. Based upon his experience, "done slowly and properly, there isn't a better product. . .it is not cheap, not easy, and the subs [subcontractors] do not like it. . .when completed, it's like a fortress around you."

A Florida builder says that almost all ICF structures will qualify as an EPA Energy STAR rated house. He downsizes the air conditioner from his typical four tons (48,000 BTU/Hr) for a 2,000 square foot house to 2.5 tons when using ICFs. This cuts his costs for the HVAC system. He also installs mechanical ventilation to increase the ventilation rate and avoid "sick building syndrome." He has observed a 33 percent energy reduction in similar model homes by using R-20 ICFs instead of wood framed houses without insulating sheathing and with R-11 batts.

A Virginia Beach, VA builder estimates that ICF construction adds two to four weeks to the construction schedule, because of shipping issues and due to required setting and bracing before the concrete pour. However, he finds the trade-off well worth it for this kind of construction.

The Chestertown, MD builder involved in the *Demonstration Homes Project* subcontracts the same framing crew for both ICF and wood-frame construction. After experiencing high costs and delays in building their first ICF home due to problems obtaining a local concrete pumping truck, the framers asked if they could buy a portable concrete pumper to do their own pouring. The lower costs due to the use of this portable pumper paid for the pumper after the first job. This has lowered the framing costs on subsequent homes along with providing better service.

A builder in Iowa has his own crew install the ICF block and rents the concrete pump truck. Using his own crew decreases the material requirements as there is typically greater control of materials ordered and less waste at the end of the job. In one case, there were approximately 20 to 25 blocks of waste out of 918 blocks ordered (2.7 %).

Marketing

ICF homes are typically marketed based on their energy efficiency, comfort, noise abatement and weather resistance. Builders feel that ICFs set them apart from the competition, but that selling ICFs is "a constant educational process." Most customers are unfamiliar with the product. Builders set up booths at home shows, give site tours, and have ICF displays to introduce the concept. ICFs may appeal to those interested in new technologies and energy efficiency more than the average public.

One builder from Iowa has mentioned that product differentiation is not an issue as far as buyers are concerned -- "customers don't really care, [and] are more concerned with amenities."

When selling ICF houses, a Florida builder focuses on weather resistance and insulation. Mainly, he sells by word of mouth but does get a booth at local home building show. His customers see cost as the bottom line. He also discusses Energy Efficiency Mortgages (EEMs) with customers, but most don't take advantage of them because most are buying a second home and don't need the "stretch" provided by these special mortgages.

A builder in Kentucky started using ICFs in 1994 as a way to build a niche market. He was interested in energy efficiency and wanted another way to set himself apart from the competition. He builds about three to five high-end custom homes per year. He says that his customers like ICFs but they are a hard sell. He states that the people in his area are fairly conservative and that marketing ICFs is difficult. "It's a constant educational process," he stated. He sells the benefits of energy efficiency, soundproofing, and safety (he’s in a tornado-prone area). His buyers have to be willing to take his word that the houses are more energy efficient because they can't see anything different once the walls are in place. The Portland Cement Association is helping with marketing of his houses.

A builder from Virginia Beach, VA mentioned that his houses are seen by his customers as being "quite different" because of ICFs, and that is the biggest reason for his success. He reports his customers purchase his homes because of their increased energy efficiency, strength, and durability. The builder feels that ICF construction combines strength and energy efficiency in a new home system that his customers can appreciate. The Virginia Beach demonstration house was marketed and sold based on its exemplary design features, its waterfront location, and its ICF wall system. Participation in the builder’s local home show provided a large amount of publicity and exposure for the builder and the home.

Homeowner Perspective

Homeowners were interviewed as part of the NAHB Research Center's *Demonstration Homes Project* and were very positive about their satisfaction with their new homes. Among the specific reasons for homeowner satisfaction were:

- Reduced noise from the exterior
- Wide attractive interior window sills
- Reduced drafts and improved energy efficiency
- The attractiveness of new technology

In addition, homeowners may be interested in ICFs because they may offer improved strength, durability, and other benefits over conventional walls.

One homeowner felt that quietness and appearance of the wide window sills should have a positive impact on the re-sale value of the home.

One Austin, Texas builder who resides in an ICF home says that residents appreciate the solid construction of an ICF home. Customers are confident that an ICF home will withstand extreme winds experienced in their area. Other features of the home that customers appreciate include lack of sound transmission and lower utility bills. One homeowner remarked that they cannot hear the engines of the boats on the lake. They also find interior sounds are lessened in between rooms. Their ICF home is more energy efficient than their previous homes -- a winter heating bill is approximately $175 per month compared with $350 to $400 per month previously. The ICF structure complements the southwest architectural style. The owner feels that this type of construction is ideal for a stucco finish. They feel that these benefits will increase the re-sale value of the home.

Homeowners of the Virginia Beach Demonstration Home are a retired couple who viewed the home while under construction and were impressed by its appearance. After visiting with the builder and learning about ICFs, they decided to purchase the home. Features of the ICF construction they liked included energy efficiency (a strong selling point) and the new technology.

The homeowners continue to like their home and appreciate it more the longer they live in it. They consider their home to be energy efficient, soundly constructed and to have a look of "solidness" to it. The wide window sills contribute to this feeling and provide a nice area for decorating. They also appreciate how quiet it is and believe this feature will provide a marketable benefit during re-sale as the house is in close proximity to a naval air station. Low utility bills and high levels of comfort attest to the energy efficiency of the home. The homeowners report no drafts in their home. The homeowners are pleased with their home and indicated they would buy another ICF home.

Future Work

With growing use of ICFs, economies of scale may be achieved as more contractors force competition, labor becomes more efficient as familiarity increases, and more specialty products and techniques are developed.

A reduction in the number of different ICF systems and standardization of construction details between competing ICF systems could result in a reduced premium for ICF homes compared to conventional wood frame construction. The particular construction details of any ICF project are dependent on the selection of a specific manufacturer’s product. Once a particular builder has chosen an ICF system and has gone through the costly learning curve process, there is a disincentive to switch to any other ICF product. This reduces competition between ICF manufacturers.

There are also opportunities to make the systems themselves more efficient. Current concrete and other related standards, such as American Concrete Institute (ACI) 318-95, are typically based on tests involving much larger and more complex structures than typical homes. Applying the requirements of ACI 318-95 to low-rise one- and two-family dwellings results in over-design and increased construction costs. More specifically, the main concern in residential applications is that the prescribed minimum steel reinforcing requirements in ACI 318-95 are conservative for the low loading conditions of one- and two-family residences.

Contact(s)

Associations

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www.forms.org
List of manufacturer members and contractor/distributor members available by State/Province.

Cement and Concrete Promotion Council of Texas
www.ccpc-texas.org/projects.html
They maintain directory of builders, architects, manufacturers, and projects done within the state.

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Website: www.pathnet.org
Publications
Phone: 800.245.2691
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PUBLICATIONS CURRENTLY AVAILABLE ON ICFS

Taking Shelter from the Storm: Building a Safe Room Inside Your House, FEMA, 1999. Available through FEMA.

Investigation of Wind Projectile Resistance of Insulating Concrete Form Homes, Keisling and Carter, Texas Tech University, (1999). Portland Cement Association, Skokie, IL.

Structural Design of Insulating Concrete Form Walls in Residential Construction, Andrea Vrankar, NAHB Research Center, and Lionel Lemay, (1998). Portland Cement Association.

Prescriptive Method for Insulating Concrete Forms in Residential Construction, Andrea Vrankar and Nader Elhajj, (1998). NAHB Research Center, Upper Marlboro, MD.

Insulating Concrete Forms for Residential Design and Construction, Vanderwerf, Feige, Chammas, and Lemay, (1997). Portland Cement Association and McGraw-Hill.

Design Criteria for Insulating Concrete Form Wall Systems, John Roller, CTL, (1996). Portland Cement Association.

Insulating Concrete Forms: Installed Cost and Acoustic Performance, by Farkas and Pesce, NAHB Research Center (1999). HUDUSER, Rockville, MD.

Insulating Concrete Forms for Residential Construction: Demonstration Homes, Carr, Farkas, Pesce, and Rosette, NAHB Research Center (1997). HUDUSER, Portland Cement Association.

Insulating Concrete Forms, Construction Manual, Successful Methods and Techniques, Vanderwerf and Munsell, Portland Cement Association (1996). Available through PCA and McGraw-Hill.

Insulating Concrete Forms: Comparative Thermal Performance, Farkas and Johnson, NAHB Research Center, (1999). PCA, HUDUSER.

Energy Comparisons of Concrete Homes Versus Wood Frame Homes, Pieter Vanderwerf, Building Works, 1998. Portland Cement Association.

Guidelines for Using ASHRAE 90.2-1993 with ICFs, Martha vanGeem, CTL (1998). Portland Cement Association.

Technical Analysis for Sizing HVAC Equipment for ICF Homes, Bruce Wilcox, CTL, and Sizing
Air-Conditioning and Heating Equipment for Residential Buildings with ICF Walls, Martha vanGeem, CTL (1998). Portland Cement Association.

Guidelines for Using CABO Model Energy Codes for ICF Homes, Bruce Wilcox, CTL (1997). Portland Cement Association.

Technical Analysis for Using Energy Codes for ICF Homes, Bruce Wilcox, CTL (1997). Portland Cement Association.

Concrete Homebuilding Systems, Vanderwerf and Munsell, (1995), and 1999 Homebuilder Report, (1999). Portland Cement Association.

Videos

Building With Insulating Concrete Forms Video Training Series. Contact Portland Cement Association

PCA Wind Tunnel Tests. Contact Portland Cement Association

Virtual Tour of Dallas House. Contact Portland Cement Association

Glossary

In evaluating wall performance, walls are considered in sections so that, in part, the framing factor of the constituent parts of the wall can be determined. The wall can be broken into several components.

Material R-value: The resistance to heat transfer of common materials such as fiberglass, wood, concrete, or foam, usually stated in per inch of material. The higher the number, the better insulator a material is. Manufacturers of insulation typically state this value on their label.

Cavity R-value: The maximum R-value of insulating materials through the cavity of a frame wall. For this example, the cavity R-value is the sum of the R-values of the fiberglass, the plywood, and the drywall.

Clear Wall R-value: The resistance of a wall section with no windows, doors, or corners. For wood framing this is vertical studs, top and bottom plates, and one bay of insulation. For ICF construction, the wall section is a section of repeating geometry, consisting of foam forms and concrete.

Assembly R-value: The thermal resistance of a combination of framing details that go into a specific assembly, such as a window or door. For a window supported by wood framing this includes the header, sill plate, jack studs, king studs, and support studs. For a window supported in ICF construction, the assembly includes window framing material (wood or plastic), concrete and a foam form.

Overall or Whole-Wall R-value: The combined resistance of clear walls, window and door assemblies, and corners.

April 2000

DESIGNING WALLS WITH INSULATED CONCRETE FORMS

INTRODUCTION

Insulated Concrete Forms (ICFs) are typically constructed of rigid foam plastic insulation, a composite of cement and foam insulation, or a composite of cement and wood chips. The forms typically remain in place after the concrete has cured to provide an insulated concrete wall.

ICFs are typically categorized by the form of the ICF unit, such as pane, plank, and block. The main differences among these categories are the amount of concrete vs. form material required, insulating value, attachment requirements, and method of installation. ICF characteristics include the inherent strength of reinforced concrete construction in resisting high winds, reduction in the intrusion of outside noise, and resistance to damage by termites and moisture.

Although ICFs have been used successfully in the United States, Canada, and Europe for more than 20 years, broader acceptance has been limited by a lack of practical design guidelines and prescriptive requirements for residential applications. As a result, those who desire to build or purchase a home with ICF construction must incur the additional burden of engineering for each application.

ICF DESIGN

The NAHB Research Center recently completed two publications: *Prescriptive Method For Insulating Concrete Forms In Residential Construction*, and *Structural Design of Insulating Concrete Form Walls in Residential Construction*. These publications will help builders, contractors, designers and others understand how to design and use ICF systems in residential construction.

Prescriptive Design Method

A prescriptive approach to ICF design eliminates the need for engineering in most applications. *Prescriptive Method for Insulating Concrete Forms in Residential Construction* includes below-grade and above-grade wall design tables, lintel tables, construction details, thermal guidelines, and other related information for home builders, building code officials, and design professionals. The provisions of this document were developed by applying accepted engineering practices to standard construction techniques; however, users of the document should verify its compliance with local code requirements.

Funding for the research that lead to the development of the Prescriptive Method publication was provided by the U.S. Department of Housing and Urban Development and the Portland Cement Association. It is available through HUD at 202-708-3151; PCA at 800-868-6733; and the NAHB Research Center at 800-638-8556.

Structural Design Guide

For applications not specifically addressed by the above prescriptive requirements, the Research Center developed a more detailed procedure for applying accepted engineering practice entitled *Structural Design of Insulating Concrete Form Walls in Residential Construction*. This publication is a step-by-step guideline for the design of single- and multi-unit residential structures using ICF wall systems. It includes detailed design procedures, a comprehensive design example, and design aids such as graphs, charts, and tables to assist the designer.