



## Insulating Concrete Forms (ICF)

Foam forms that are filled with reinforced concrete and reinforcement bar to create insulated structural walls.

### Summary

Concrete forms have taken a new shape-and purpose. Insulating concrete forms (ICFs) are rigid plastic foam forms that hold concrete in place during curing and remain in place afterwards to serve as thermal insulation for concrete walls. The foam blocks, or planks are lightweight and result in energy-efficient, durable construction.

ICFs consist of insulating foam, commonly expanded polystyrene (EPS) or extruded polystyrene (XPS). The three basic types are hollow foam blocks, foam planks held together with plastic ties, and 4 x 8 panels with integral foam or plastic ties. ICFs can be used to form various structural configurations, such as a standard wall, post and beam, or grid. They provide backing for interior and exterior finishes. Some manufacturers use ICFs for roof and floor construction.

Insulation values of ICF walls vary depending on the material and its thickness. Typical insulation values range from R-17 to R-26, compared to between R-13 and R-19 for most wood-framed walls. The strength of ICF structures relative to lumber depends on configuration, thickness, and reinforcement.



### *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


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### PATH Attributes



ICF walls provide higher R-values (between R-17 and R-26) and lower air infiltration rates than typical wood frame construction (typically R-12 to R-20). Thermographic testing by the NAHB Research Center 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.

 Foundation walls built with ICFs may be easier and faster to construct than either CMU or CIP foundations depending on the area. 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. The walls of a properly-constructed ICF home are exceptionally resistant to loads imposed by high winds and can be designed for all seismic zones. With regard to 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.

 Wind Resistance and Seismic Resistance. See Benefits/costs area for details.

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#### Ease of Implementation



Appropriate concrete placement equipment (such as a pump truck) may not be available in some locations distant from metropolitan areas. Some concerns exist for ICF use below grade because some plastic foams may not be accepted by some building codes due to the potential for termite infestation. ICFs change the construction sequence, which requires a greater amount of coordination initially.

Methods for attaching interfacing materials is different from traditional building materials and is frequently met with resistance by trade contractors. For example, utilities must be routed behind the wall surface by cutting grooves in the foam.

There are many manufacturers of ICFs-some distribute directly to concrete contractors or builders, while others distribute through authorized building products distributors.

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#### Initial Cost

ICF material cost ranges from about \$1.75 per square foot to about \$3.50 per square foot in addition to installation labor, reinforcement, bracing, and concrete.

ICF homes cost about two to five percent more than wood-framed construction.

However, they may be cost-competitive when installed in combination with certain wall exteriors such as exterior insulation and finish systems (EIFS), which can be applied directly to the foam without additional substrate.

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Operational Cost  
Not Applicable

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#### U.S.Code Acceptance

ICFs must meet standard prescriptive structural design requirements for cast-in-place concrete walls in the building codes. The plastic foam insulation on the interior surface requires special attention to meet fire resistance provisions. The International Residential codes (IRC) contain prescriptive methods for building below- and above-ground grade walls. The National Evaluation Service (NES) has reviewed and accepted ICFs systems, and has issued National Evaluation Reports (NER). On February 1, 2003, America's four building-product evaluation services officially combined their operations under the International Code Council. The four "legacy" evaluation services that came together to form ICC-ES were the National Evaluation Service, Inc.; BOCAI Evaluation Services; ICBO Evaluation Service, Inc.; and SBCCI Public Service Testing and Evaluation Services, Inc. Information on these NERs can be obtained by contacting NES at their web site.

#### ***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).

The first edition of the Prescriptive Method for Insulating Concrete Forms in Residential Construction represented the outcome of an initial effort to fulfill the need for prescriptive construction requirements and to improve the overall affordability of homes constructed with insulating concrete forms. The first edition also served as the source document for building code provisions in the International Residential Code (IRC).

The second edition of this document (Prescriptive Method) was published in January of 2002 and expanded on the first edition by adding provisions for Seismic Design Categories C and D (Seismic Zones 3 and 4). Wall construction requirements utilizing Grade 60 reinforcing steel and concrete mixes with selected compressive strengths were included. In addition, tables throughout the document were simplified.

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 first edition of the *Prescriptive Method* was accepted for inclusion in the International Residential Code (IRC) and the Standard Building Code (SBC). The

IRC includes provisions for the use of ICFs in both above- and below-grade applications. Bear in mind that the IRC is a model code, that States or localities must adopt and they have the option to add or remove requirements as they see fit. There is also a typical time from the publishing date of the model codes to 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.

ATTRIBUTE	MAXIMUM LIMITATION
<b>GENERAL</b>	
Number of Stories	2 stories above grade plus a basement
Design Wind Speed	150 mph (241 km/hr) 3-second gust (130 mph (209 km/hr))
Ground Snow Load	70 psf (3.4 kPa)
Seismic Design Category	A, B, C, D1, and D2 (Seismic Zones 0, 1, 2, 3, and 4)
<b>FOUNDATIONS</b>	
Unbalanced Backfill Height	9 feet (2.7 m)
Equivalent Fluid Density of Soil	60 pcf (960 kg/m <sup>3</sup> )
Presumptive Soil Bearing Value	2,000 psf (96 kPa)
<b>WALLS</b>	
Unit Weight of Concrete	150 pcf (23.6 kN/m <sup>3</sup> )
Wall Height (unsupported)	10 feet (3 m)
<b>FLOORS</b>	
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)
<b>ROOFS</b>	
Maximum Roof Slope	12:12

Maximum 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 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 2003 Edition of the International Residential Code (IRC), prohibits the use of foam insulation below grade and within six inches above grade in heavily-termite infested areas. 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](mailto: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.

Bruce Davis Construction: Washington Square, La Plata, Maryland  
Hopke Buildings & Grounds: MADE to Last Home, Sturgeon, Missouri  
Hughes Construction: Lexington, North Carolina

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## Installation

ICFs are commonly installed on standard spread footings or on-grade concrete slabs. Layout lines are snapped and the ICFs stacked or set in place, typically in an interlocking fashion. Steel rebar is placed where required in the hollow cores. Concrete is poured, typically with a concrete pump, and is consolidated with care so not to create a "blowout," or to rupture the form.

After curing, standard construction materials are used to complete the roof, floors, and interior walls.

Interior and exterior finishes are applied to the foam.

### *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.

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.

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. 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. 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. 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. 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 be 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 guidelines 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.

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.

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 residential construction; however, determining how much less may be difficult.

#### ***Attachment of finishes***

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.

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#### Warranty

Warranties vary by manufacturer, but typically cover any damage to the structure to faulty manufacture for a period of 25 to 30 years.

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#### Benefits/Costs

ICFs allow trade contractors to construct concrete walls without a significant investment in reusable wood and metal forms. Because they use non-biodegradable materials, they are not subject to rot as is untreated lumber. They can increase the temperature range for pouring concrete to below freezing (freezing inhibits proper curing) by insulating the concrete until fully cured. ICFs can also result in a higher strength wall than standard cast-in-place concrete due to more constant, predictable cure during all seasons.

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 require 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.<sup>4</sup>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-17 and R-26)<sup>5</sup> 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*<sup>3</sup> 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.

<b>Table 3. TYPICAL R-VALUES OF MATERIALS</b>		
<b>Material, thickness</b>	<b>R-value per inch of material</b>	<b>R-value for given Thickness</b>
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 <sup>±</sup> 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.

	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+ %

Location	Total Extra Cost	% Increase in Final Sales
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.

Total	\$4,114
<b>Wood-Framed Wall Construction</b>	
<b>Framing Costs</b>	
Material	\$722
Installation	\$843
Total	\$1,565
<b>Energy Features Costs</b>	
Material	\$396
Installation	\$104
Total	\$500
<b>Total Wall Cost</b>	
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.

<b>Table 8. Demonstration Houses Normalized Wall Costs</b>			
Location	Construction Type	Installed Cost per Floor Area (ft <sup>2</sup> )	Installed Cost per Wall Area (ft <sup>2</sup> )
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.

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Endnotes:

1. PCA Wind Tunnel Tests
2. VanderWerf, Peiter, *Insulating Concrete Forms*
3. VanderWerf, Pieter
4. NAHB Research Center, Inc., *Demonstration Homes Project*

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Please visit Path's website at [www.toolbase.org](http://www.toolbase.org) for additional and up to date information about this subject.