ICFs—Under the Microscope

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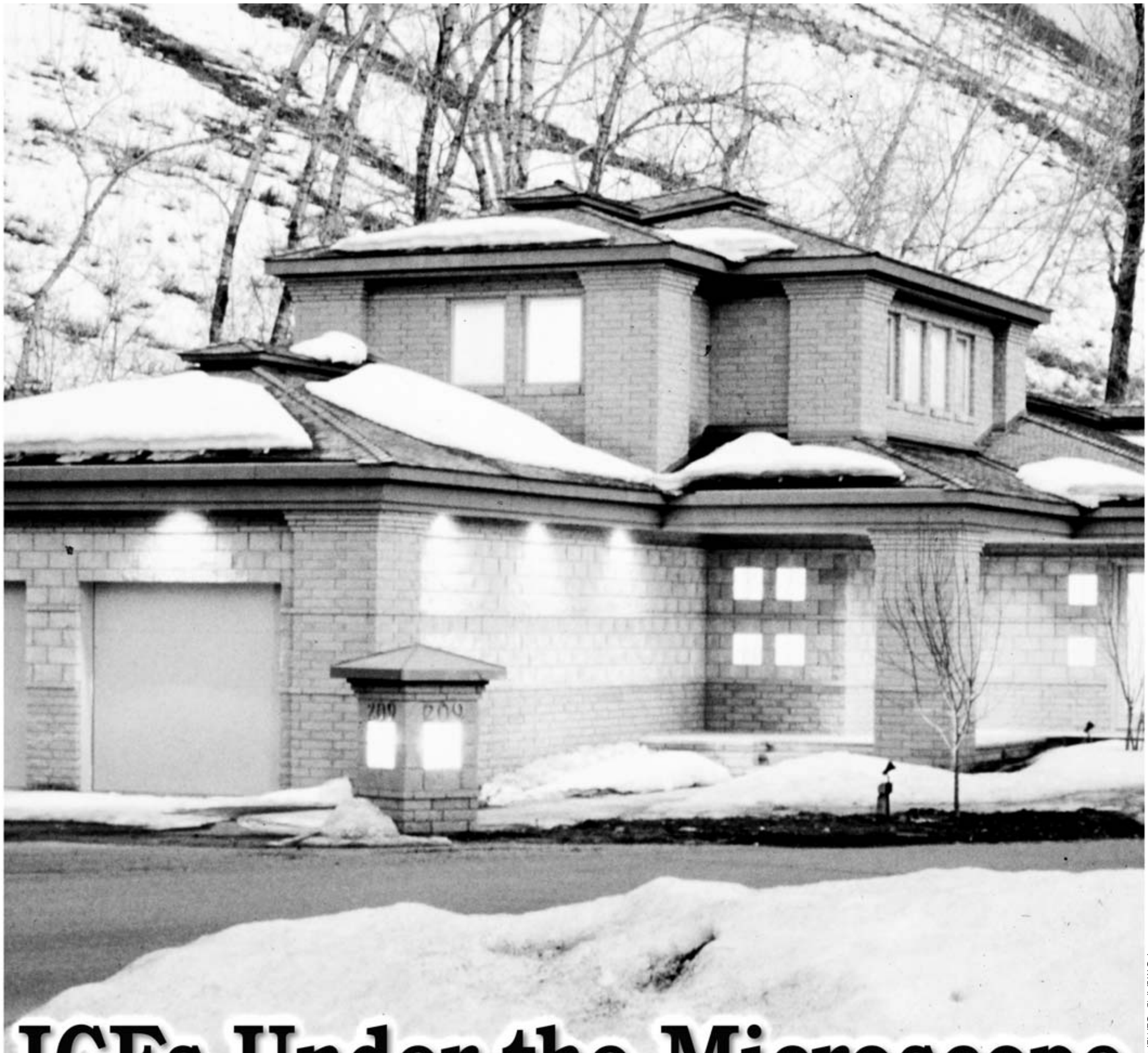
PORTLAND CEMENT

ICFs Under the Microscope

by Mary James

Build almost identical homes, varying only one component—what the walls are made out of—and then carefully monitor the performance of the nearly twin homes. That's the recipe that two teams of researchers used to better understand the impact of building with insulating concrete forms (ICFs). For some additional fodder, Ecotope's Bob Davis weighs in with his experiences with ICFs on pg. 41.

Fraternal Twins

A side-by-side view of a stick-built and an ICF-built house reveals some surprises.

Thermally massive construction techniques can provide comfortable, sturdy, aesthetically pleasing, environmentally friendly, and energy-efficient building envelopes. In particular, high-mass walls made with concrete can have environmental advantages compared to stick-built homes (see "Concrete's Green Tones," p. 6). But depending on the specific type of concrete wall assembly and on local construction and materials costs, these advantages may not outweigh the costs. To get a more detailed understanding of the energy implications of building with insulating concrete forms (ICFs), Jeff Christian and a team from Oak Ridge National Laboratory built two side-by-side houses that were identical in every respect except for their wall construction materials.

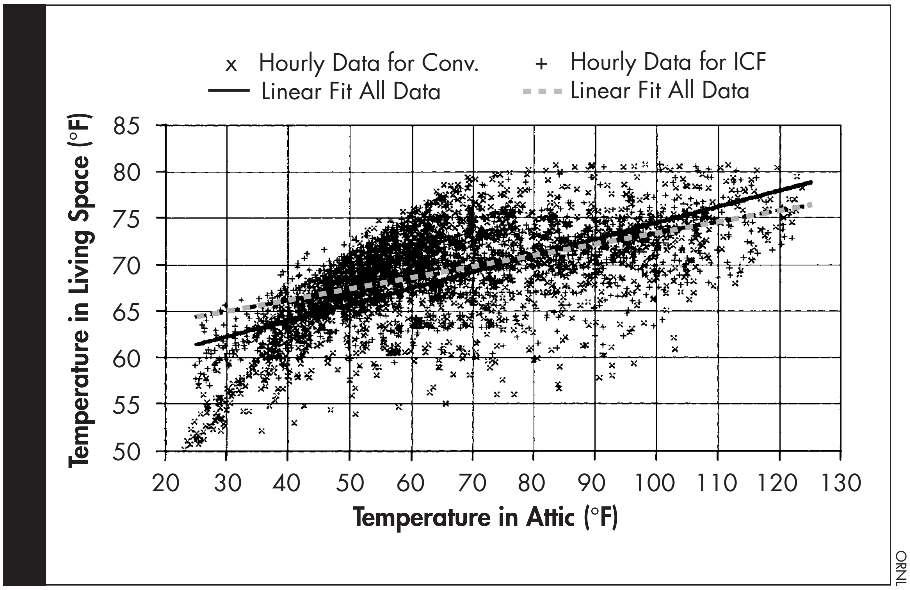

Figure 1. For 15 weeks during the swing seasons, the air temperatures in the houses were allowed to float.

A team of building scientists and Habitat for Humanity volunteers completed the construction of the two homes near Knoxville, Tennessee, in April 2000. Each house is a 1,094 ft^2 single-story dwelling. In both houses the ceiling and floor R-values are identical (see Table 1). The stick-built house achieved a whole-wall R-value of R-11. The whole-wall R-value of the ICF walls was R-15. Cooling was provided by a 12-SEER 2-ton heat pump. Electric-resistance heaters supplied the heat.

The unoccupied homes were monitored extensively for 11 months, beginning in July 2000. During the summer and winter the thermostat was kept at 72°F. For a total of 15 weeks during the spring and fall, the heat and A/C were turned off. Duct leakage measurements showed that the two building teams had installed comparable duct systems. Air leakage to outside at 25 Pa as a percentage of the nominal supply air flow rate was 7.7%–7.9% in the ICF house and 7.9%–8.7% in the conventional house.

How Tight?

Christian's team conducted blower door tests three times during the 11-month testing period (see Table 2). On average, the ICF home was about 10% tighter than its conventionally built counterpart. Christian attributes the changing blower door test results over the year to seasonal effects. In winter, when the wood shrinks, the houses are leakier. With summer temperatures and humidity, the wood swells and the homes are tighter.

In addition to wanting to nail down the effect of ICFs on infiltration, Christian also wanted to compare the impacts of thermal mass on temperature swings in the house. For 15 weeks of anticipated mild weather, from late September through mid-November and from mid-March until early May, in the swing season between heating and cooling, the heating/cooling systems were turned off in the houses. The air temperature was allowed to float at whatever level the outside conditions dictated.

Christian chose attic air temperature as the variable against which to plot living space temperature, because he believes that attic temperature should give a better measure of changes in outside conditions than outside air temperature alone (see Figure 1). The attic air temperatures ranged from 25°F to 125°F during the swing season. The hourly temperatures in the living space of the ICF house remained relatively comfortable. The hourly temperatures in the living space of the conventional house never got too hot, but the house did get too cold during this time. As the large scatter of the data about the linear fits shows, living space temperatures without heating or cooling do not correlate well to attic temperature alone. However, Christian interprets the shallower slope of the line for the ICF house as a further illustration of the narrower range of fluctuations of air temperatures in the ICF house.

Different, but Not That Different

The measured total electricity usage for the calendar year July 2000 through June 2001 (including the estimate of usage in June 2001) was 12,200 kWh for the conventional house and 11,200 kWh for the ICF house. The ICF house used 7.5% less energy than the conventional house when unoccupied and with

Table 1. Features of the Side-by-Side Houses

Feature	ICF House	Conventional House
Ceiling R-value	28.4 h·ft²·°F/Btu	28.4 h·ft²·°F/Btu
Floor R-value	17.9 h·ft²·°F/Btu	17.9 h·ft²·°F/Btu
Exterior Wall R-value	15.0 h·ft²·°F/Btu	10.6 h·ft²·°F/Btu
Leakage/Floor Area	0.00038	0.00042
Crawlspace Ventilation	0.1 cfm/ft²	0.1 cfm/ft²[1]
Heat Transfer Coeff. with Crawlspace Floor	1.0 Btu/(h·ft²·°F)	0.5 Btu/(h·ft²·°F)
Duct Air Loss to Outside/Supply Air	7.7% to 7.9% (used 7%)	7.9% to 8.7% (used 7%)

1 Crawlspace ventilation rate in the conventional house was twice this value during summer before adjustment of louvers on the vents.

Table 2. Results of Blower Door Tests

CFM_{50}	June 2000		Conv.	March 2001		Conv.	May 2001		Conv.
	Conv.	ICF	-ICF	Conv.	ICF	-ICF	Conv.	ICF	-ICF
Test 1 [1]	784	707	77	1,109	1,046	63	958	845	113
Test 2 [2]	742	658	84	1,079	996	83	914	799	115
Test 3 [3]	593	459	134	905	840	65	723	617	106
Test 4 [4]	560	448	112	900	809	91	687	592	95

1 Test 1: No seals and open all internal doors, including those to closets.
2 Test 2: Like test 1, except seals over supply outlets and return grille of duct system.
3 Test 3: Like test 2, except seals also over vents and attic access hatch.
4 Test 4: Like test 3, except seals also over the windows and one of two outside doors. The other was used for the blower door.

Table 3. Modeled Annual Electricity Use for Various Locations

	Cooling (kWh)		Heating (kWh)		Total (kWh)		
City	Conv.	ICF	Conv.	ICF	Conv.	ICF	% Diff.[1]
Phoenix	2,800	2,650	2,920	2,440	7,540	6,900	8.5
Phoenix (3 Ton)	3,130	2,980	2,920	2,440	7,870	7,230	8.1
Minneapolis	890	820	15,260	13,920	17,970	16,550	7.9
Dallas	2,230	2,120	5,450	4,840	9,500	8,780	7.6
Boulder	750	690	9,460	8,620	12,030	11,130	7.5
Knoxville	1,490	1,450	7,460	6,770	10,770	10,040	6.8
Miami	2,550	2,440	380	230	4,750	4,490	5.5

1 (Conv. Total – ICF Total)/Conv. Total · 100

limited loads. Only electric-resistance heat was used for heating, and during heating and cooling, circulation fans were continuously on. The annual totals included the periods when no heating or cooling was turned on during the spring and fall, despite times when occupants would be likely to use heating or cooling rather than open or close windows to keep the house comfortable.

To generalize the results of this research, validated models of the side-by-side houses were used to predict the difference in energy consumption due to ICF construction if the houses were located in different climates (see Table 3). Not surprisingly, the greatest energy savings from the high-mass walls occurred in Phoenix, where diurnal temperature swings are the largest. Miami's more consistent temperature throughout the day—almost always hot and humid—meant that the high-mass walls provided the least benefit in that climate.

The construction of these nearly identical homes allowed for a fairly detailed comparison of a stick-built home to one built with ICF walls. The ICF-built home was tighter and used less cooling energy than the stick-built one—but the differences were not large.

For more information:

Petrie, Thomas W. et al. "How Insulating Concrete Form vs. Conventional Construction of Exterior Walls Affects Whole Building Energy Consumption: Results from a Field Study and Simulation of Side-by-Side Houses." *Proceedings* of 2002 ACEEE Summer Study on Energy Efficiency in Buildings. Available on CD-ROM from the American Council for an Energy-Efficient Economy (ACEEE).

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ICFs in North Texas

DAVE CHASAR

DAVE CHASAR

Two Centex Homes home models were built twice—once with ICFs and once with traditional wood frame construction. The smaller model *(pictured at top)* encompassed 2,861 ft^2. The larger one *(bottom)* was 3,767 ft^2.

Just outside Dallas, Texas, two sets of duplicate homes provided the setting for another analysis of how building with insulating concrete forms (ICFs) affects cooling energy use. Two Centex Homes home models—a 3,767 ft^2 model and a 2,861 ft^2 one—were constructed twice. One of each model was built with typical wood frame construction and one each using ICFs. All four homes were two stories with the front door facing north. SEER-12 heat pumps provided the air conditioning.

Researchers from the Florida Solar Energy Center (FSEC) installed remote data loggers in each of the four homes. They collected hourly readings of indoor and outdoor temperature, relative humidity, furnace run-time fraction, total building electrical energy, and HVAC energy use from January through August 2000. Each home was tested to determine building airtightness and the amount of duct leakage (see Table 1).

Advocates of ICF homes claim airtightness is a benefit of ICF construction. In fact, the envelope airtightness measurements show that in the larger model the ICF home was indeed tighter than the frame home, but in the smaller model the situation was reversed. FSEC's Dave Chasar suggested that this difference could be attributed to the fact that only the walls of the ICF homes were constructed differently from those of the frame structures; the slab-on-grade foundation and wood-framed roof designs were similar. Construction details at the attic and at the junction of the first and second floors are critical to a home's airtightness, as is the amount of duct leakage.

Even with this variability in the ICFs' impact on airtightness, the ICF-built homes used 17%–19% less cooling energy than did the stick-built homes (see Table 2). These homes were all occupied during the monitoring period, and the researchers adjusted the energy data for two occupant impacts—miscellaneous loads and thermostat settings. First, the daily cooling energy in each frame home was reduced by subtracting the difference in miscellaneous energy between each ICF and frame home pair while factoring in the coefficient of performance of the air conditioning equipment. Second, HVAC energy use was calculated using the difference in temperature across the building envelope to help account for thermostat settings.

Other occupant impacts, such as how much the residents pulled down their shades, could not be accounted for, and neither could certain construction differences. Despite efforts to build each pair of homes with identical construction except for the wall assemblies, there were two oversights: The color of the exterior brick differed between the two pairs and an attic radiant barrier was absent in one of the ICF homes.

The solar absorptance level of exterior walls can have a measurable effect on the space-cooling load. This effect is even more pronounced in two-story homes where the wall surface area is much greater than it is in single-story construction and where roof overhangs are less beneficial. In the larger-model homes, the frame home had the lighter, more favorable brick color, while the ICF home had the lighter brick color in the smaller model.

Three of the homes had radiant barrier laminated to the underside of the

Table 1. Building Construction & Airtightness Details

Construction	ICF	Frame	ICF	Frame
Model	E2051	E2051	E50	E50
Floor Area (ft^2)	3,767	3,767	2,861	2,861
Heat Pumps 1st /2nd fl.	5 ton/ 4 ton	5 ton/ 4 ton	4 ton/ 2.5 ton	4 ton/ 2.5 ton
Glass/Floor Area	18%	18%	13.5%	13.5%
Attic Radiant Barrier	No	Yes	Yes	Yes
Exterior Brick Color	Red w/ Black Tint	Red	Red w/ Pink Tint	Red
CFM_{50}	2,701	3,105	2,632	2,426
ACH_{50}	4.3	5.0	5.6	5.1
$CFM_{25\ total}$	620	742	602	674
$CFM_{25\ out}$	268	407	296	385
Occupancy	6	4?	4	4

Notes:
- All homes are 2-story with the front facing north.
- All windows are double pane, clear glass, aluminum frame, U=0.81.
- All attics have R-30 blown insulation.
- SEER 12 heat pumps were designed to run until the outside temperature dropped below 47°F after which natural gas backup heat came on (no electric strip heat).

roof decking to reduce radiant-heat transmission to the second-floor space. The larger-model ICF home, however, had no radiant barrier and received a greater cooling load as a result.

These inconsistencies make it more difficult to compare the energy impact of the two construction styles. The researchers did run several simulations using DOE-2 to check their measured results. One set of simulations held all details of the homes constant except for the wall construction. This simulation resulted in a 13% cooling energy savings for the ICF home.

Both the measured and simulated savings indicate that ICFs have an edge over stick-built homes in a North Texas climate. However, the variability in airtightness among the different model sets shows that building a home with ICF walls won't guarantee a tight home for a homeowner. As is so often true, airtightness results are all about the details. Finally, no details were provided on what extra costs were borne to reap these cooling energy savings.

*Mary James is the publisher of **Home Energy**.*

Table 2. Measured Seasonal Cooling Savings

Model	Type	Slope	Intercept (kWh)	Energy	Cost	Savings	Adj. Savings
E2051 (3,767 ft^2)	Frame	1.486	19.71	4,448	$356	22.9%	18.9%
	ICF	1.351	13.90	3,429	$274		
E50 (2,861 ft^2)	Frame	0.999	12.41	2,862	$229	20.8%	16.8%
	ICF	0.932	8.95	2,268	$181		

Notes:
Energy = [slope x (82.3 – 76) + intercept] x 153
Where: 82.3 = average summer ambient temperature (°F)
76 = average cooling setpoint (°F)
and 153 = Dallas cooling season (May 1 through September 30)
Frame home energy was reduced to account for differences in miscellaneous energy use
Final savings values were reduced 4% to account for duct leakage differences
Utility rate of $0.08/kWh used to obtain cost savings

For more information:

Chasar, Dave et al. "Measured and Simulated Cooling Performance Comparison: Insulated Concrete Form Versus Frame Construction." In *Proceedings* of 2002 ACEEE Summer Study on Energy Efficiency in Buildings. Available on CD-ROM from the American Council for an Energy-Efficient Economy (ACEEE).

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Buyer Be Aware

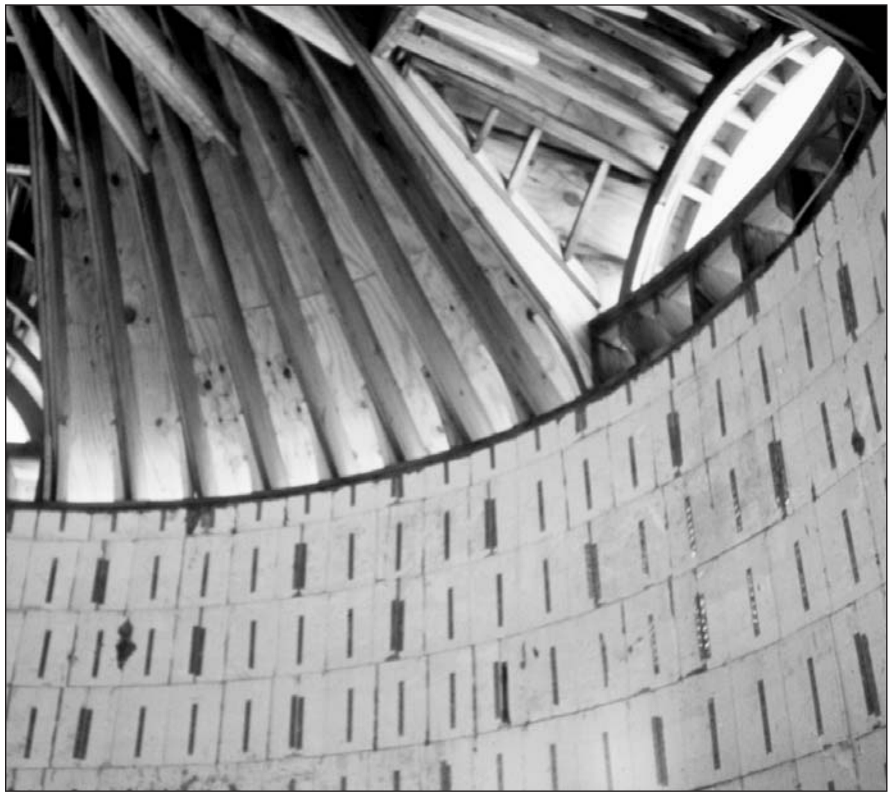
by Bob Davis

Over the past several years, we have evaluated six ICF wall assemblies in the context of assessing compliance with regional energy codes. Depending on the product, the above-grade U-value—as determined by using Frame or Therm, the standard NFRC simulation tools—varies from virtually the same as a 2 x 6 frame wall insulated with fiberglass batts to more than 25% better.

Infiltration can be expected to be lower in structures constructed from ICFs, as long as attention is paid to the detailing at the bottom and top plates and rough openings. But a blanket assertion that a home will always be tighter if built with ICFs is irresponsible; only infiltration testing will prove this.

Similarly, there appear to be cooling season benefits from an assembly that has more thermal mass than light-frame construction does. However, in many climates, especially in the northern tier, the mass effect is slight or nonexistent. This climate-dependent advantage must be made clear to prospective buyers, as must the cost premium for this type of system.

Depending on the product chosen, the climate, and the care taken in installation, ICFs can offer benefits over traditional light-frame construction—for a price. Consumers should scrutinize this building option with the same thoroughness as they would give to all the other options they consider when building a home or business.



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