By Martha VanGeem and John Gajda

Energy Efficiency of Concrete Homes

Compared with homes with frame walls, even with much more added insulation, concrete saves energy.

Houses with exterior concrete walls, also called *mass walls,* use less energy to heat and cool than similarly insulated houses with wood or steel frame walls. This is a known fact, but because identical wood frame and concrete houses are rarely built side-by-side, computer modeling is the only way to quantify the energy savings. The CTLGroup, Skokie, Ill., analyzed houses in 25 cities to determine the energy-saving effects of concrete mass walls.

Houses and wall construction

CTLGroup modeled a typical 2450 square-foot single-family house (about average for new homes) with a current design to determine energy use in 25 places across the United States and Canada. Locations were selected to represent a range of climates. The study considered houses with a variety of concrete wall construction types, and homes with wood frame and steel frame walls. The concrete walls included those constructed of concrete masonry units (CMU), insulating concrete forms (ICF), autoclaved aerated concrete (AAC) blocks, and insulated concrete hybrid walls with exterior insulation, interior insulation, or internal insulation. Sketches of the walls are shown in Figures 1 through 5.

In the study, the walls, windows, and roof were insulated to meet or exceed the minimum energy code requirements of the 2000 International Energy Conservation Code (IECC) for U.S. locations, or the 1997 Model National Energy Code of Canada for Houses for Canadian locations, as appropriate. The 2000 IECC is currently the most commonly adopted energy code in the United States, although a 2004 version is now available. To perform the modeling, we used energy simulation software that used the Department of Energy's (DOE) 2.1E calculation engine. This model calculates energy use hourly, helping to properly determine thermal mass effects.

The wood frame walls had insulation with an added R-value (the amount of insulation added, not including the R-value of the exterior cladding, interior gypsum wallboard, concrete, or framing) of R11, except in the following locations: Chicago was R13, Fargo (N.D.), Toronto, and Winnepeg were R19, and Halifax and Quebec City were R19 with additional insulation sheathing. The steel frame walls had R11 added insulation except in Boston, Boulder (Colo.), Springfield (Ill.), Chicago, Fargo, Halifax, Quebec City, Toronto, Winnepeg, and Vancouver where the insulation was R19 rated.

Frame and concrete wall results

The houses with ICF flat panel walls had R16 added insulation and saved energy compared with the houses that had wood and steel frame walls in all climates—including those with higher R-values. Also, houses with ICF waffle-grid walls, with R8 added insulation, saved energy when compared with houses with frame walls in all climates except Halifax and Quebec City where frame walls have R30 added insulation—more than three times greater than the ICF.

The sandwich panel walls tested had R10 added insulation, and their energy saving results were similar to the ICF waffle-grid walls, saving energy in all climates except Halifax and Quebec City.

Figure 1: Typical frame wall sections

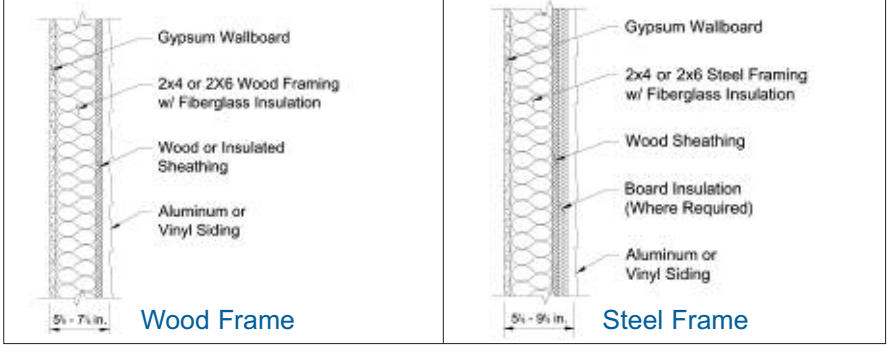
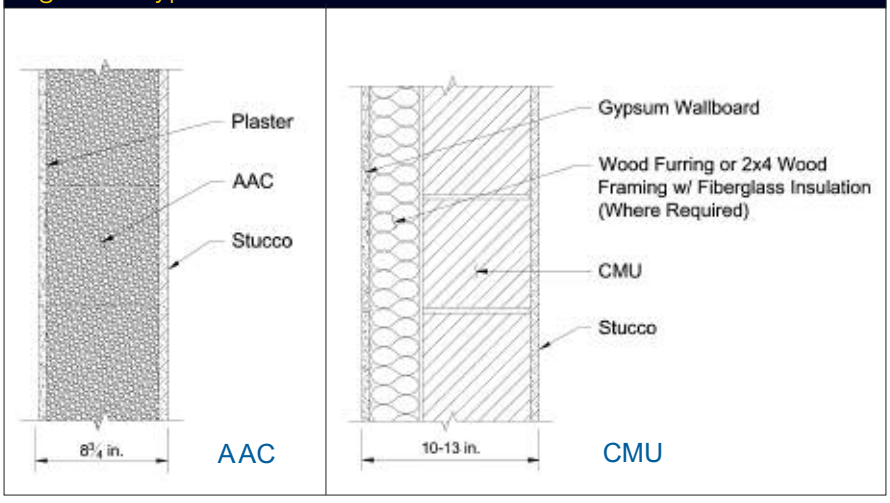


Figure 2: Typical AAC and CMU wall sections



Cast-in-place concrete walls also had good results. With R8 (2-inch-thick polyfoam on the outside of the wall) added insulation, the system saved energy in all climates except Halifax, Quebec City, Fargo, Toronto, and Winnepeg. The frame walls in these cities had much more insulation.

Houses built with CMU walls had R11 added insulation except in the following locations: Chicago, where the requirement is for R13 added insulation; Fargo, Toronto, and Winnepeg where the requirement is R19 added insulation; Halifax and Quebec City where the requirement is for R13 added insulation plus additional insulation sheathing. In Houston, Miami, Tampa, Los Angeles, and Phoenix there was no added insulation. Insulated CMU walls saved energy compared with houses with wood and steel frame walls in all climates except Quebec City, where the added R-value was more than twice as much for the frame walls. And homes with CMU walls with no added insulation in Los Angeles saved energy compared with houses that had frame walls with R11 added insulation.

The houses with AAC walls had no added insulation and saved energy compared with houses with wood and steel frame walls in milder climates such as Houston, Fresno, Los Angeles, San Francisco, Tampa, and Miami. The steel framing in a wall significantly reduces the effectiveness of the added insulation. For instance, an R11 insulation batt in a steel frame wall with studs at 16 inches on center has an effective R-value of 5.5. With studs at 24-inch centers, the effective R-value is 6.6.

The study also revealed that homes with exterior mass walls save the most energy in seasons when the outdoor air temperature during the day floats above and below the balance point of the house, about 60° F.

Sensitivity analyses

We performed sensitivity analyses to determine the effect of building orientation and air leakage; the effects of orientation were significant. Houses with more east and west facing windows typically use more energy. For the sake of analyses, rates of air infiltration for all houses were assumed to be identical, although in actual practice, mass walls almost always have a lower rate of air infiltration than frame walls. A comparison using average air leakage rates into houses based on construction type (mass or frame walls) showed significant additional heating and cooling energy cost savings due to less air infiltration and the mass effect of the walls.

HVAC systems

Another benefit of housing with mass concrete walls is that they showed additional savings from a reduction in the required heating and cooling system capacity. Homes with concrete mass walls required smaller heating and cooling systems than homes with frame walls, except in locations where the concrete walls had much less insulation than frame walls. But since cooling units are usually bought in increments of ½ ton of cooling capacity, the cost savings for the smaller sizes may not always be realized.

Figure 3: Typical ICF wall sections

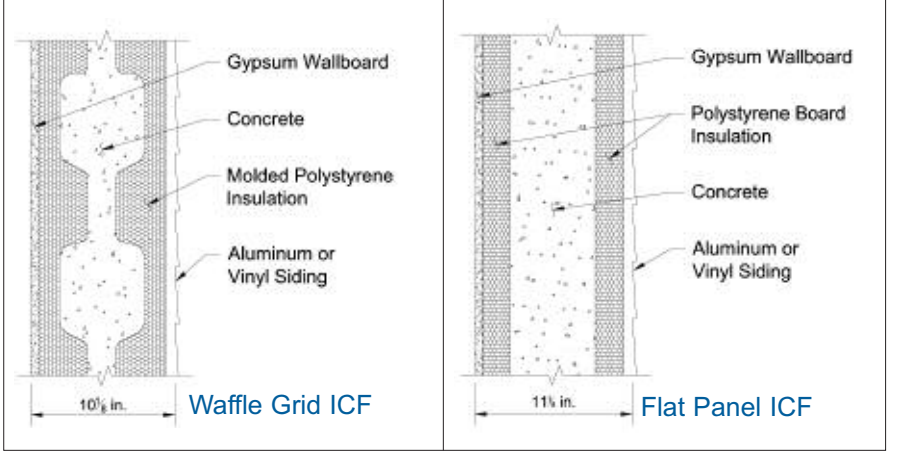
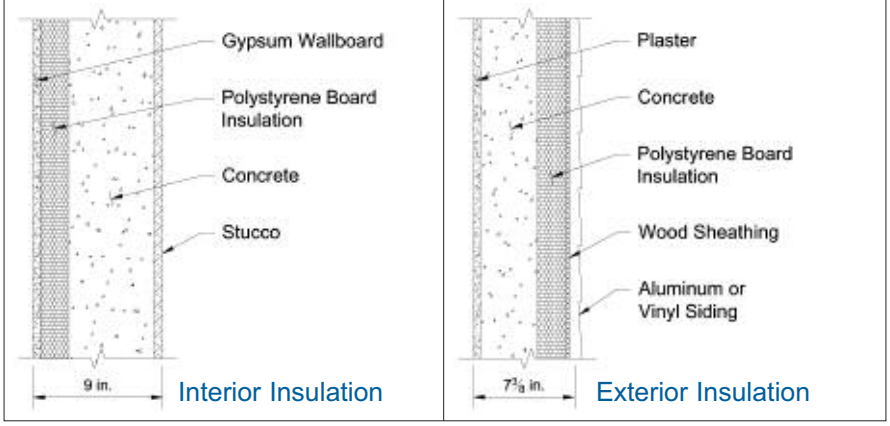


Figure 4: Typical cast-in-place wall sections



were identical for all locations. Indoor temperature set points and occupant habits were identical for all wall types and locations. Annual energy use is based solely on heat flow through exterior walls (a function of the U-factor or R-value of the wall) and the ability of the exterior walls to moderate the indoor temperature (a function of the thermal mass of the wall). Frame walls have insignificant thermal mass, while concrete walls can have a high thermal mass. Concrete walls with more or less insulation than shown in this study are available.

Heating and cooling systems in houses with concrete walls generally cycle less frequently than those with frame walls because the concrete houses have less air infiltration and are more energy efficient. HVAC systems that bring in supply air from outdoors and circulate air on a regular basis are recommended for these homes. These are sometimes referred to as "air handlers" or "air-to-air handlers." They prevent stale air and odors from accumulating. But more importantly, they help prevent the accumulation of moisture on and within walls and other building components. Oversized air conditioning systems can cause additional moisture problems because they don't cycle enough to adequately remove indoor moisture.

Over-insulated frame walls

Due to the use of typical construction materials such as fiberglass batt insulation in frame walls and CMU walls in some locations, walls were over-insulated when compared with the energy codes. Because the concrete walls were constructed using identical materials and quantities in all locations (polyfoam insulation is a standard thickness for ICF walls, and 2 inches thick for other cast-in-place wall systems), concrete walls were under- or over-insulated, depending on the location.

Analysis

All the homes analyzed using the computer model for the study were slab-on-grade and the overall window-to-exterior wall ratio was 16%. Concrete walls were constructed using commonly used materials, quantities, and dimensions, and

Analyses showed that energy for occupant uses, and hot water was essentially identical for all locations, about 8500 kilowatt hours annually. Total energy use includes occupant uses as well as heating and cooling energy. Heating and cooling energy accounted for 17% to 65% of the total annual energy cost, depending on the exterior wall type and location.

Summary

In all climates, homes with concrete walls save energy compared with homes with frame walls that have more added insulation—and the savings can be significant. The full 50-page report is available for $20 on CD number 026, "Energy Use of Single-Family Houses with Various Exterior Walls" from the Portland Cement Association at www.cement.org.

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Figure 5: Typical sandwich panel wall sections