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INDUSTRY NEWS

An Illinois "Passivhaus"

Since 1977, when Gene Leger built his first double-walled house in Pepperell, Massachusetts, thousands of superinsulated homes have been built in North America. In recent years, however, much of the cutting-edge work in superinsulated house design has occurred in Europe—especially in Germany, where the Passivhaus Institut of Darmstadt has been promoting a set of technical standards for superinsulated homes (see ***EDU***, February 2004).

In hopes of developing more awareness of the Passivhaus standards among US builders, architect Katrin Klingenberg recently built an all-electric house in Illinois complying with the Passivhaus guidelines developed in Germany. Klingenberg came to the US from her native Germany in 1994 to get her master's degree at Ball State University. In recent years Klingenberg has focused much of her professional attention on energy efficiency and sustainable building.

Last year, Klingenberg decided it was time to build her own house on a lot in Urbana. She designed a simple shed-roofed house insulated on all six sides to at least R-56, and contracted with Chicago builder Ed Sindelar to build it (see Figure 1).

A Colder Climate

Klingenberg knew that the Passivhaus standards would have to be tweaked a bit to work in Illinois. "The program specifications were written for Germany," she says. "But the climate here in Illinois is way more severe." In fact, according to ASHRAE, Champaign/Urbana has a 99% winter design temperature of -3°F, significantly colder than the comparable numbers for Berlin (7°F), Amsterdam (20°F), or Paris (22°F).

Klingenberg used computer modeling to refine the specifications of her thermal envelope. Energy considerations dictated the house's thick walls and its box-like shape. "The surface/volume ratio has to be very good, so you do not want to have a lot of nooks and things sticking out of your house, because you lose energy," Klingenberg explains.

The foundation of the Klingenberg house is a concrete-block frost wall surrounding a slab. The 9 ⅝-inch-thick block wall is insulated on the exterior with 6 inches of expanded polystyrene foam, protected above grade with slate. The slab was poured over a 14-inch-thick layer of expanded polystyrene, built up from seven layers of 2-inch insulation board, for a total R-value of 56 (see Table 1, page 3).

Walls Framed With I-Joists

Klingenberg framed the thick walls of her house with vertical 12-inch TJIs (I-joists from Trus Joist). Trus Joist has developed details allowing their TJI floor joists to be used as studs; however, since US builders show little interest in superinsulation, the publication is available only in German. (The document, which has the unlikely title of "Balloon und Platform Framing Details," is posted on the Web at *www.trusjoist.com/PDFFiles/GE-R05.pdf*.)

According to Klingenberg, when TJIs are used as studs, they require structural sheathing on both sides. For interior sheathing, Klingenberg specified OSB, which functions as a vapor retarder. On the exterior, Klingenberg wanted a more vapor-permeable sheathing; she settled on ½-inch Stedi-R structural fiberboard (R-1.28) from Georgia Pacific.

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Figure 1. Architect Katrin Klingenberg's superinsulated house in Urbana, Illinois conforms to standards established by the Passivhaus Institut of Darmstadt, Germany. The house's simple, box-like shape minimizes its surface-to-volume ratio. On the west side of the house, the fresh air intake duct and exhaust duct can be seen where they emerge from underground.

Figure 2. The exterior polystyrene partially laps the window frames. The builder used exterior jamb extensions and wood window sills to trim the edges of the polystyrene and the rainscreen strapping.

The exterior fiberboard was topped with two layers of 2-inch-thick expanded polystyrene, secured by vertical strapping screwed through to the studs. The exterior polystyrene was installed so that it partially overlapped the window frames. The strapping creates a rainscreen drainage cavity behind the cedar bevel siding (see Figure 2). After the cavities between the TJI studs were filled with blown-in fiberglass, the wall had insulating materials with a total R-value of about R-60 (see Figure 3).

The top and bottom wall plates are doubled 1¼″ by 11 ⅞″ Tiberstrand rim boards. Since the polystyrene insulation on the exterior of the concrete-block foundation wall is 2 inches thicker than the polystyrene on the exterior of the framed walls, the walls were cantilevered beyond the foundation by 2 ½ inches. This overhang allows the cedar siding to shed rain beyond the slate-protected foundation foam.

To maintain the integrity of the air barrier, the house's exterior walls have no electrical boxes; instead, receptacle boxes are mounted in the floor. The light switches at exterior doors are not hard-wired to the fixtures they control. Klingenberg specified battery-operated wireless light controllers from Lutron, installed in shallow surface-mounted boxes.

Cold Roof

The shallow-pitched roof is a single south-facing plane framed with 16-inch TJI rafters and insulated with blown-in fiberglass. Klingenberg designed a "cold roof" with two layers of exterior roof sheathing sandwiching a vent channel; the lower layer of sheathing is vapor-permeable structural fiberboard, and the upper layer is OSB. The roofing is standing-seam galvanized steel. Klingenberg hopes that some day she will be able to afford to install Uni-Solar peel-and-stick photovoltaic modules on her metal roof.

Triple-Glazed Windows

The south face of the Klingenberg house has most of the windows: a total of 190 square feet of fixed glazing and casements. A carefully designed roof overhang protects the south-facing glazing from summer sun.

The fiberglass-framed windows were manufactured by Thermotech of Ottawa, Ontario. All of the windows have triple-pane, argon-filled, low-e glazing. The glazing for the south, east, and north windows has a relatively high solar heat gain coefficient (SHGC) of 0.51, while on the west side (the orientation most likely to cause overheating) the glazing has a lower SHGC of 0.31.

The Thermotech windows Klingenberg specified for the south side have an overall U-factor of 0.17. According to her research, they are the best available in North America; however, she would have preferred windows with an even lower U-factor. Although Klingenberg claims that some German manufacturers produce triple-glazed windows with better performance specs than Thermotech windows, Steven Thwaites, the owner of Thermotech, disagrees. "In Europe, a different procedure is used for calculating window U-factors," says Thwaites. "If we calculate our U-factor as 1, the Germans would say the same window has a U-factor of .9—it would be 10 percent lower. We don't need to hang our heads in shame when we compare our windows with German windows meeting the Passivhaus standard."

Figure 3. The 12-inch-thick walls were insulated with Optima blown-in-place fiberglass insulation.

In April 2004, Klingenberg visited Darmstadt, Germany, to consult with Dr. Wolfgang Feist, the director of the Passivhaus Institut. During her visit she learned that her house could have achieved Passivhaus standards even if it had double-pane rather than triple-pane windows, and even if it had somewhat lower levels of wall and roof insulation. Moreover, a new round of computer modeling indicates that her Illinois home may be susceptible to overheating during sunny weather in winter or spring. If overheating proves to be a problem, some method of shading the windows may prove useful.

An Electric Water Heater

Klingenberg's domestic hot water is produced by a $450 instantaneous electric water heater from a German manufacturer, Stiebel Eltron. "The experience in Germany is that solar thermal systems require a lot of maintenance and have the tendency to break," says Klingenberg. "I considered a geothermal loop, but eventually decided it couldn't be justified because of its very high initial cost—about $5,000. It simply didn't make economic sense; the energy savings would have never made up for it."

Dr. Feist agrees that in most cases, investing in an active solar thermal system yields lower levels of energy savings than investing in insulation. "We don't calculate payback times—not on houses and not on solar thermal systems," says Feist. "Instead we look at the annual energy cost and at interest costs. We can calculate the cost per kilowatt-hour saved from adding insulation, and compare that to the cost of including a solar thermal system. Solar thermal is by far the highest cost of any of the features we are discussing at the moment."

Sophisticated Mechanical Ventilation

Although Klingenberg's house was built with meticulous attention to air sealing—with all panel joints glued or taped—it has never been tested with a blower door. To ventilate her tight home, Klingenberg chose a heat-recovery ventilator (HRV) from Germany, the Westaflex WAC 250, because of its sophisticated controls (see

Table 1—Klingenberg House Specifications

Location	Urbana, Illinois
Area	1,450 square feet, including loft
Foundation	Concrete-block frost wall
Foundation perimeter insulation	6 inches of expanded polystyrene (R-24)
Under-slab insulation	14 inches of expanded polystyrene (R-56)
Wall framing	Vertical 12-inch TJIs
Wall insulation	12 inches blown-in fiberglass plus 4 inches of exterior rigid polystyrene (R-60)
Roof framing	16-inch TJIs with vent channels above the sheathing
Roof insulation	16 inches of blown-in fiberglass (R-60)
Airtightness	No blower-door testing has been performed
Windows	Thermotech windows with triple-pane, argon-filled, low-e glazing
Ventilation system	Westaflex WAC 250 heat-recovery ventilator
Heating system	Electric resistance element in the HRV
Domestic hot water system	Stiebel Eltron instantaneous electric water heater

Table 1. Katrin Klingenberg's all-electric house in Urbana, Illinois has an unusually well insulated shell.

Figure 4). By controlling mechanical dampers, the Westaflex HRV selects between two different air intake ducts, one of which is buried. The ventilation system's "earth tube" is 8 inches in diameter and 100 feet long. (Although Klingenberg used schedule 40 PVC for the buried duct, polyethylene pipe would have raised fewer concerns over possible outgassing.)

The HRV control adjusts the intake dampers based on data from an outdoor temperature sensor located on the north side of the building. In cold weather, outdoor air is drawn in through the earth tube, where it is warmed by the soil. Once the outdoor temperature rises to 55°F, the HRV control closes the damper on the earth tube intake and opens the damper on the duct connected to the conventional exterior intake grille. If the outdoor temperature rises to a point equaling the indoor temperature, the HRV control bypasses the heat-recovery function. (Since the Klingenberg house has no air conditioning, heat recovery makes no sense during the summer.) If the outdoor temperature rises further, the HRV control opens the earth-tube damper,

Figure 4. The Westaflex WAC 250 is a heat-recovery ventilator that can control dampers that select between two possible air intake ducts, depending on the outdoor temperature. It also includes a 1,000-watt electric resistance element to heat the house.

so that the temperature of the incoming fresh air is lowered by the relatively cool earth.

The Westaflex WAC 250 has three speeds, ranging from 53 to 177 cfm, and costs about $1,600.

Low-Cost Electric Heat

The shell of Klingenberg's house is so well insulated that she chose to use electric resistance heat. For most of the year, the house requires no supplemental heat at all. The 1,000-watt (3,141 Btu/h) electric heating element is integrated with the HRV. Last January, her electric bill (for all household uses, including heat) totaled only $35 (340 kWh), in spite of the fact that the month included two cloudy weeks and temperatures as low as -10°F.

Because superinsulated houses have such low utility bills, Klingenberg believes they are particularly appropriate for low-income housing. However, wider adoption of superinsulation techniques is unlikely to occur unless construction costs drop. "The goal would be for these houses to cost no more than $5,000 extra up front," says Klingenberg. "If we produce these homes and they are outrageously expensive, they won't catch on. We need to solve the economic side of the problem."

Klingenberg's own house cost $110 per square foot, more than she would have liked. "It was a prototype," she says. "It took a lot of research, translation of certain materials, and experimenting. But the construction is actually standard balloon framing, and it is my belief that an experienced contractor could build such a house for about 10 percent more than a comparable home—an amount that could be easily recovered in energy savings over ten years."

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