

## Volume 19, No. 9; September 1999

Copyright 1999 Aspen Publishers, Inc. All rights reserved. No part of this document may be reproduced in any manner without express written permission from Aspen Publishers, Inc.

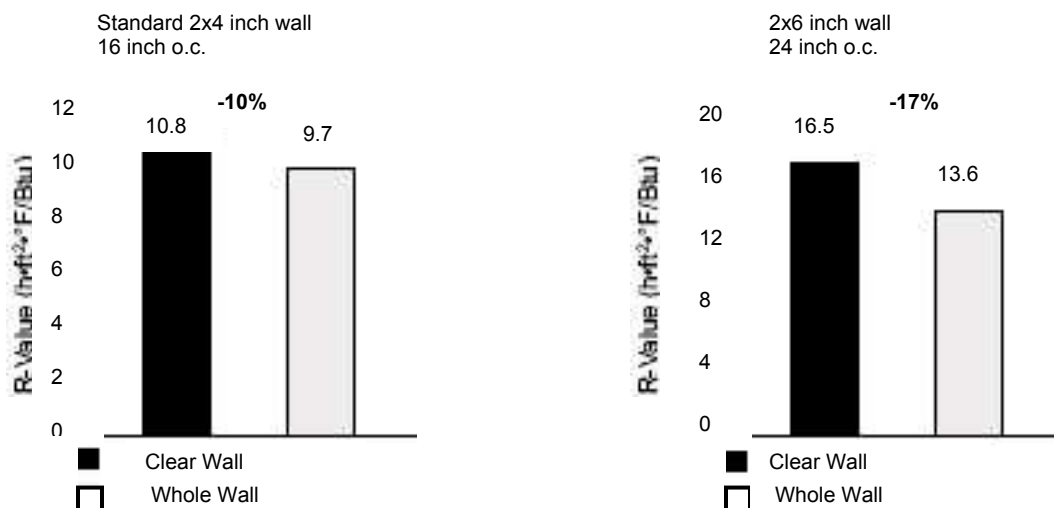
### How Thermal Shorts and Insulation Flaws Can Degrade an “R-19” Stud Wall to a Measly “R-11”

Much has been written, in *EDU* and elsewhere, about the generally poor quality of insulation work in the field and the industry’s efforts to improve the status quo. But not much research has been done to quantify the thermal penalties associated with poor installation.

Now comes research from Oak Ridge National Laboratory (ORNL) that sheds an interesting new light on the performance of stick-built, batt-insulated walls.

Since 1994, the research team at ORNL’s Buildings Technology Center has been laboring to quantify the true, whole-wall performance of various wall systems. Whole-wall analysis includes the impact of interface details (e.g., wall-corner, wall-floor, wall-ceiling, and window and door surrounds) on the wall’s performance. As explained in the sidebar, “ORNL’s Online Calculator: A Work in Progress,” the team’s long-range mission is to create an interactive Web-based calculator that will let designers accurately compare dozens of wall systems, taking thermal shorts, mass effect, air tightness, etc., into account.

At this point, researchers have a good understanding of the opaque, whole-wall performance of stick-built, fiber-glass-insulated walls. As shown in Figure 3, guarded hotbox measurements find that the clear-wall performance (excluding interface details) of nominal “R-11” and “R-19” walls is actually R-10.8 and R-16.5, respectively. When the impact of interface details is factored in, the whole-wall R-values become R-9.7 and R-13.6, respectively. The calculations were done for a standard North American ranch house, as described in Figure 3.



**Figure 3** – Stick-and-batt construction has diminishing returns as higher R-values are pursued. The calculations were done for a standard North American ranch house that has been the subject of previous energy modeling studies. The single-story house has 1,540 ft<sup>2</sup> (143 m<sup>2</sup>), with eight double-pane windows, two doors, one glass slider, and R-30 attic insulation

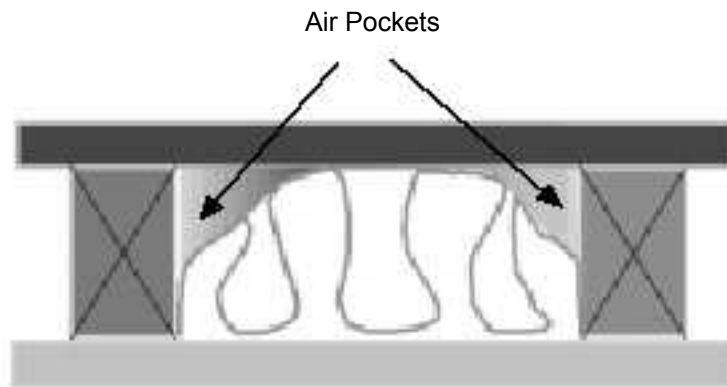
For designers and homebuilders who are weighing the differences between 2x4 and 2x6 construction, there's some real food for thought here. Using the nominal R-values as a point of comparison, one might boast of getting 73% more insulating value by upgrading from 2x4 (R-11) to 2x6 (R-19) construction. But when the measured clear-wall numbers are used — 10.8 versus 16.5 — the advantage suddenly shrinks to 53%. And when the whole-wall R-value — the most accurate metric for comparison — is used, we find that the 2x6 wall is really only about 40% better than the 2x4 wall (e.g., 13.6 versus 9.7). In this light, other possible wall assemblies, such as 2x4 framing with insulating sheathing, become relatively more attractive.

#### *Adding Real-World Elements*

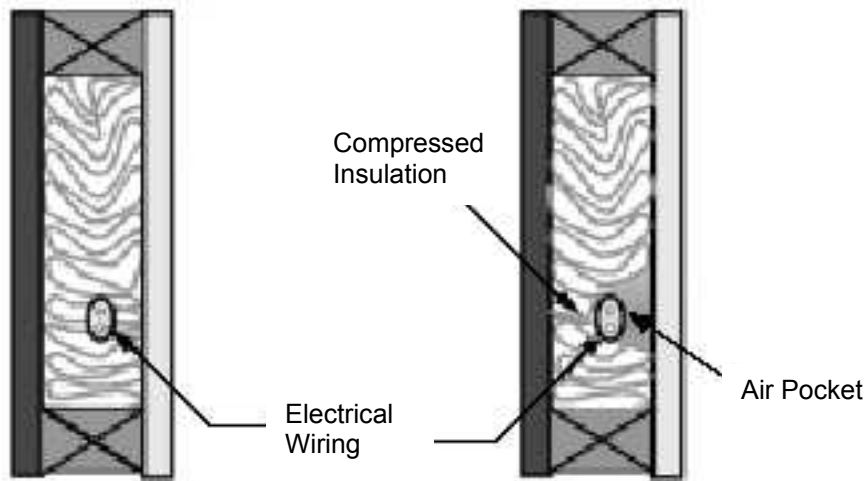
All of the R-values presented above assume that the fiberglass batt is perfectly installed, with no electrical wires or plumbing in the wall. But that's not the way houses are really built, is it?

With that in mind, the ORNL research team decided to further measure the performance of the 2x6 wall, adding what one might call "real-world elements" to the picture. In the first test, they installed a switch box at mid-height and an electrical duplex box 14 inches (36 cm) from the bottom of the 8x8-ft (2.4x2.4-m) test wall. An electrical wire connecting the switch to the box was placed squarely in the middle of the cavity. The fiberglass batt was precisely cut and perfectly fit to close on either side of the wire, creating a "best practices" installation. As shown in Table 4, the whole-wall R-value fell from 13.6 to 12.8, a loss of about 6%.

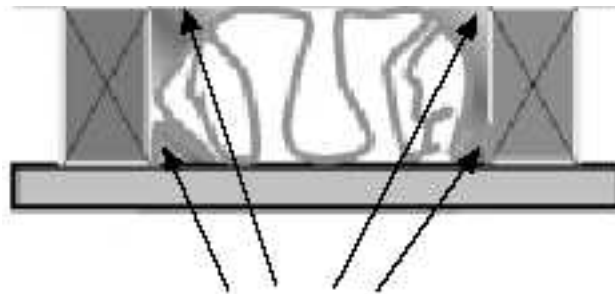
The researchers proceeded with a series of tests that one-by-one introduced installation flaws that are typical of real-world installations. These include insulation installed with rounded shoulders (Figure 4), insulation compressed around electrical wiring (Figure 5), voids, and insulation with the facer stapled to the inside of the stud (Figure 6). Table 4 shows how these types of imperfections degrade the real R-value of a wall. Note that in the worst-case scenario, in which the test wall had batts with rounded shoulders, 2% cavity voids, and the paper facer stapled to the stud, the R-value was reduced 14% from the idealized installation (benchmark) and a whopping 42% from the nominal R-19 that builders and homeowners often expect.



**Figure 4—Batt with rounded shoulders.**



**Figure 5—Insulation compressed due to electrical wiring.**



**Figure 6—Rounded shoulders and facer fastened to inside of stud.**

### *The Mysterious Absence of Convective Heat Loss*

The ORNL research team had speculated that the loss of R-value might be even more serious in those test walls that featured batts with rounded shoulder and voids in the cavity. Theoretically, those walls should have suffered serious convective currents inside the cavity, increasing the heat loss through the wall. But convective currents produced a surprisingly small impact, even when the temperature difference across the test wall was increased to 80°F (27°C) — that is 20°F (7°C) on the outside and 100°F (38°C) on the inside.

“We’re not certain why there wasn’t more heat loss in those test cases where the potential existed for natural convection,” says ORNL’s Jeff Christian. “One possibility is that there was no pressure-driven airflow into or out of the cavity to induce convection. The hot box tests were all conducted with a uniform near-zero air pressure difference across the wall.”

*Editor’s note: More details on this subject are available in the paper The Whole Wall Thermal Performance Calculator — On The Net by Jeff Christian, Jan Kosny, Andre Desjarlais, and Phillip Childs. The paper is part of the proceedings from Thermal Envelopes VII. In an upcoming issue of EDU, we’ll report on other whole-wall evaluations that have been completed at ORNL.*

Table 4—How Imperfections Affect the Whole-Wall R-Value of a 2x6 Batt-Insulated Wall

Test Assembly <sup>1</sup>	Whole Wall R-Value	Percent
2x6 @ 24" o.c.; w/ batts Perfectly installed	13.6	
2x6 @ 24" o.c.; w/electrical box and wiring; batts perfectly installed	(Benchmark) 12.8	
2x6 @ 24" o.c.; w/ batts with rounded shoulders	12.2	-5%
2x6 @ 24" o.c.; batts with rounded shoulders and compressed around wiring <sup>2</sup>	11.7	-9%
2x6 @ 24" o.c.; batts with rounded shoulders <sup>2</sup> , 2% cavity voids <sup>3</sup> ; no compression around wiring.	11.4	-11%
2x6 @ 24" o.c.; batts with rounded shoulders <sup>2</sup> , 2% cavity voids <sup>3</sup> ; paper facer stapled to the inside of each 2x6 stud; no compression around wiring.	11.0	-14%

1 The 8x8-foot test walls included 1/2 -inch gypsum board on the interior and 5/8-inch plywood sheathing on the exterior.

2 Created linear air pockets with no insulation around the entire perimeter of each cavity space

3 Voids were created by cutting 1-inch strips off the top and bottom of each batt in each cavity.

### ORNL's Online Calculator: A Work in Progress

Designers who are interested in comparing the whole-wall R-value of different wall assemblies should take a trip to Oak Ridge National Laboratory's (ORNL's) Web site: [www.ornl.gov/roofs+walls/whole\\_wall](http://www.ornl.gov/roofs+walls/whole_wall). Therein resides an interactive design tool called the Whole-Wall Thermal Performance Calculator, which is both a functioning design tool and a work in progress. For more than three years now, researchers at ORNL have been patiently testing various wall systems and using the data to build the calculator.

At this juncture, you can submit a simple description of custom building plans and use the interactive tool to compare the whole-wall R-value of at least 40 different wall systems. Among these are traditional stick-and-batt assemblies, structural insulating panels, structural insulated panels with compressed straw core, conventional steel C-stud frame (2x6 and 2x4); conventional metal frame with different types of sprayed foam insulation (2x6 and 2x4); novel metal studs; autoclaved concrete block; structural straw bale, and insulating concrete forms.

Jan Kosny, ORNL research scientist, says there are plans to add even more variations in the months ahead.

#### *Still Bigger Fish To Fry*

Longer term, ORNL plans to expand the whole-wall rating procedure to incorporate four other performance criteria:

- Thermal mass effect (dynamic effect)
- Infiltration (airtightness relative to typical wood-frame construction)
- Moisture control (durability)
- Sustainability (lifecycle environmental impacts)

Work is well under way on integrating the effects of thermal mass on wall performance. The introduction of Equivalent Wall Theory, which simplifies the complex geometry of three-dimensional heat flow into a one-dimensional form that can be used with DOE2.1E or BLAST software, was a strong step forward (see *EDU*, February 1999). But the work is complex and needs a concerted, well-financed research effort, says Kosny, who is helping to organize a new public-private research effort called the Thermal Mass Consortium (see details on page 5).

ORNL is also creating test protocols and collecting data on air infiltration. While there's a lot of infiltration data around that quantifies leakage rates for whole buildings, ORNL wants to isolate the amount of infiltration that's attributable to walls. The plan is to run lots of blower door tests on different