#3486

MEASURED SAVINGS

To Insulate a Basement

by Maureen Quaid

The first measured savings from foundation insulation are in. Even in well-insulated homes, foundation insulation cut space-heating use by 19%. As a bonus, homeowners got more livable basements out of the deal.

The first priorities for weatherizing small homes are clear-cut: attic and wall insulation, and infiltration reduction. After installing these measures, what's left for homeowners and landlords who want to wring more savings from their buildings? In the last several years, many researchers, program operators, code officials, and builders have made the leap to the next increments in envelope measures—efficient windows and foundation insulation.

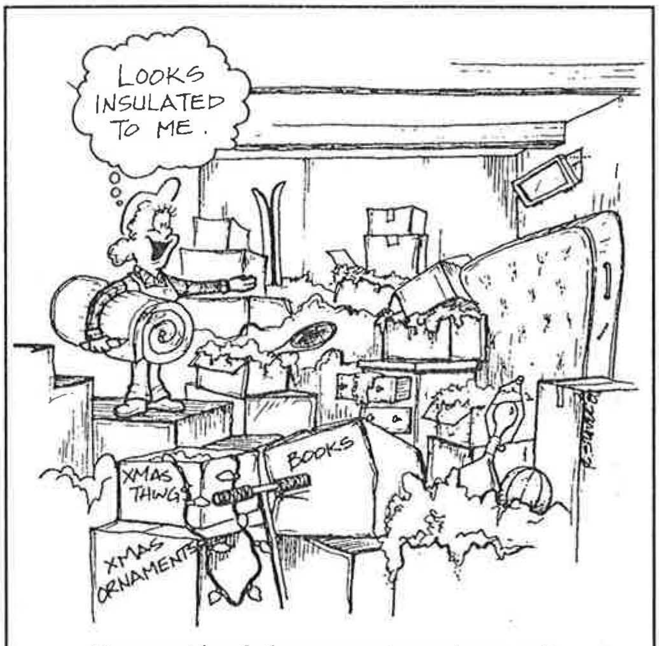
Uninsulated basements can account for 10 to 30% of the total heat loss in a home, according to Ray Sterling, researcher at Minnesota Underground Space Center.[1] If that home is otherwise well-insulated, the proportion may rise to as much as 50%. The potential energy savings from foundation insulation in the United States could reach half a quad (or 20 million tons of coal) per year, with most of the savings coming from northern climates. Yet foundation insulation is installed in very few existing homes in the United States and an only slightly larger proportion—still a minority—of the new homes.

The primary problem with the measure, and the reason it is not more widespread, is that the cost of installation is fairly high, and the savings potential has been unknown. Among other issues, this article will address the cost-effectiveness of foundation insulation, both as a retrofit in existing homes and as a component of new construction.

Foundation Insulation as a Retrofit

In 1988, the Minneapolis Energy Office completed a study in Minneapolis that measured energy savings from foundation insulation as a single retrofit.[2] This was the first time such a study has been done in North America, and perhaps the world. We undertook the study primarily to isolate and measure the actual energy savings from foundation insulation. We also surveyed the homeowners involved to discover their motivations and perceptions regarding the work, to identify concurrent changes that might affect the savings analysis, to discuss any problems that might affect the savings analysis, and to discuss any problems with the insulation that might have arisen since its installation. The study found substantial energy savings, but because the retrofit cost was high, the simple payback periods were about 20 years.

The homes in this study, all single-family homes in Minneapolis, received foundation insulation through the Minneapolis Energy Office's Operation Insulation Program. Since 1983, the program has offered low-interest loans and weatherized more than 4,000 houses and small apartment buildings. City-certified contractors performed the guaranteed work.



Basement insulation contractor arrives on site to discover her work already done.

Rick Stover

Program consultants usually recommend attic and wall insulation as well as house doctoring (infiltration reduction). They generally do not recommend foundation insulation or other retrofits such as window or furnace

Maureen Quaid, now an evaluation analyst for the Washington State Energy Office, conducted the foundation insulation study for the Minneapolis Energy Office.

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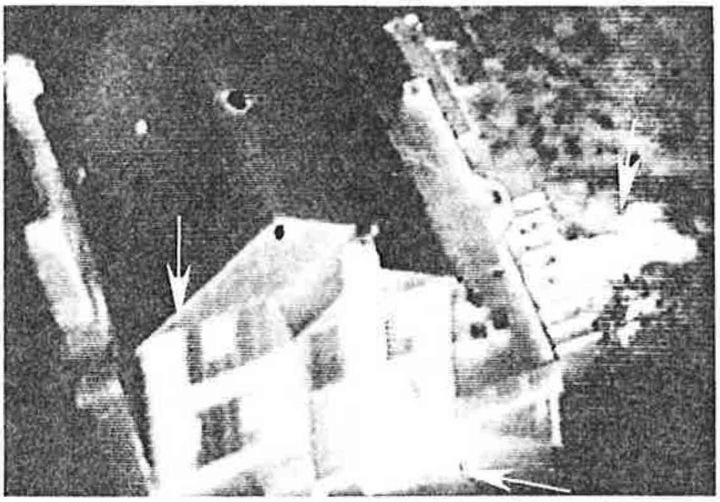

Aerial, Ultra-High Resolution Imagery reveals this home has large areas of un-insulated wall, on the first and second floors. Also detected is a typical high heat loss, which is seen on the basement block walls and masonry chimney. This survey also revealed a leaking septic main, which is noticeable to the right of the deck steps.

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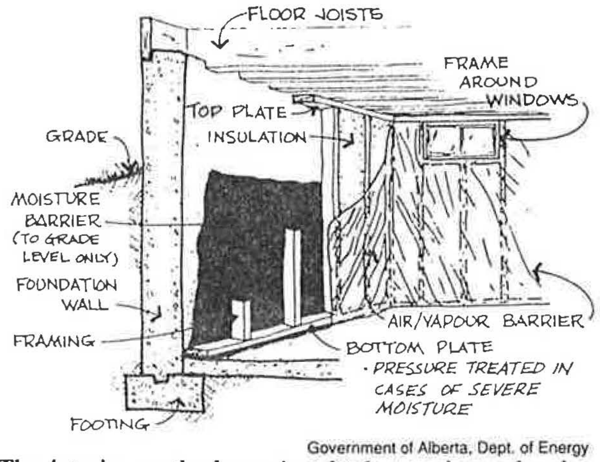


The interior method requires both a moisture barrier against the foundation and a vapor barrier between the insulation and drywall.

replacement, except where such replacement is necessary. This is because, as retrofits, these measures were not considered cost-effective. But if homeowners already have insulated their walls and attic and still want to make energy improvements, or if they have a particular interest in foundation insulation, the consultants can bid a foundation insulation job.

About 115 homes have had this particular work done in the past five years, of which 32 had no other major weatherization work done by the Operation Insulation Program within a year of the foundation insulation. Of this 32-home sample, we eventually dropped 17 cases from the study due to poor utility data, the existence of other confounding retrofits, the fact that less than 50% of the basement perimeter was covered by insulation, or because the volume of heated space in the home had changed. (In several homes, insulation of the foundation allowed homeowners to make the basement a livable space. Of course, where the furnace is in the basement, it often already is a more or less conditioned space. We eliminated homes where heat was added intentionally to the basement.)

We analyzed the remaining 15 cases by the PRInceton Scorekeeping Method, known as PRISM[3], a computerized model that estimates weather-normalized annual gas consumption before and after a retrofit. The analysis normalized for basement temperature as well. All 15 homes were heated with natural gas.

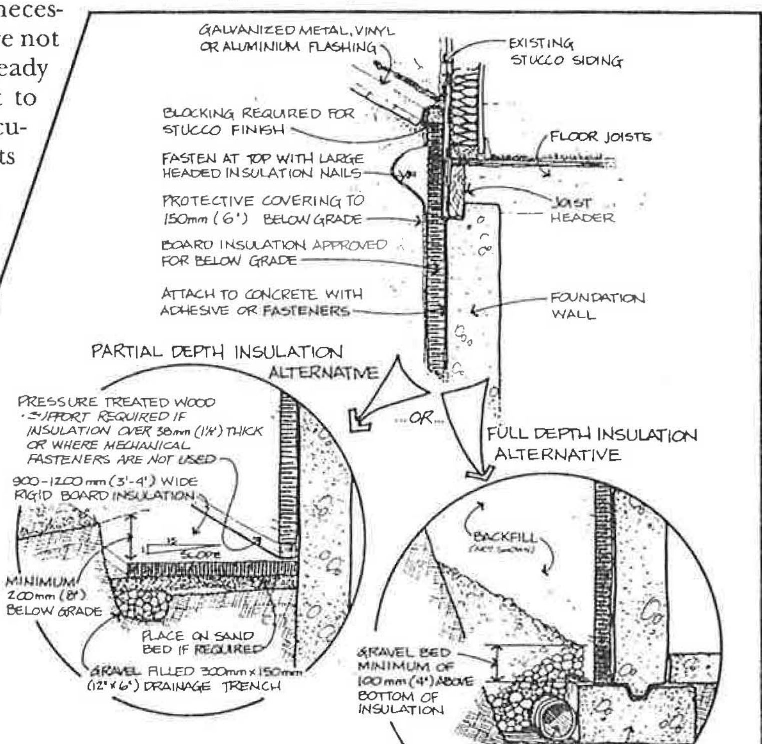
The study homes had lower-than-average gas usage before the retrofit, probably because they already had attic and wall insulation. Among these homes, eight foundations were insulated from the interior, five from the exterior, and in two homes a combination of methods was used to work around obstructions.

Interior Method

For interior jobs, the contractors built a 2" x 4" stud frame from floor to joist against the cement foundation in the basement. They sandwiched R-11 fiber-glass batts between 6-mil polyethylene vapor/moisture barriers on both sides of the batts. They taped the outermost moisture barrier either to the wall at grade level or, in cases where the basement wall surface was uneven or in poor condition, to the rim joist or top plate. They then ran the plastic beneath the bottom sill plate and trimmed it even with the finished surface. The contractors also installed gypsum board, taping and mudding it and leaving it ready for light sanding. The base price was $2/sq.ft. with an additional charge to caulk and insulate the rim joist.

Exterior Method

For exterior jobs, the contractors dug a trench around the house perimeter deep enough to accommodate a four-foot sheet of rigid-board insulation, which they attached with a drip cap above the first-floor bottom plate, where possible. This was usually sufficient to cover the basement wall to the frost line, which averages 42" deep in Minneapolis. They attached two inches of extruded



Exterior foundation insulation may reach either to the frost line or the full depth of the foundation, depending on how much you want to spend and how much you want to save.

polystyrene (R-10), using adhesives and anchor bolts. All junctures were caulked, all seams taped, and all openings flashed weather tight. A cement-based finish with an acrylic bonding agent was trowelled on, down to 4" below grade. Then they backfilled the trench and graded it to slope away from the basement wall. To avoid air gaps between the insulation and irregular foundation walls, they filled gaps with pieces of fiber-glass batts before attaching the rigid board. The base price was $2.95 per sq.ft., with an additional cost for an aggregate rock coating.

Choosing the Best Method

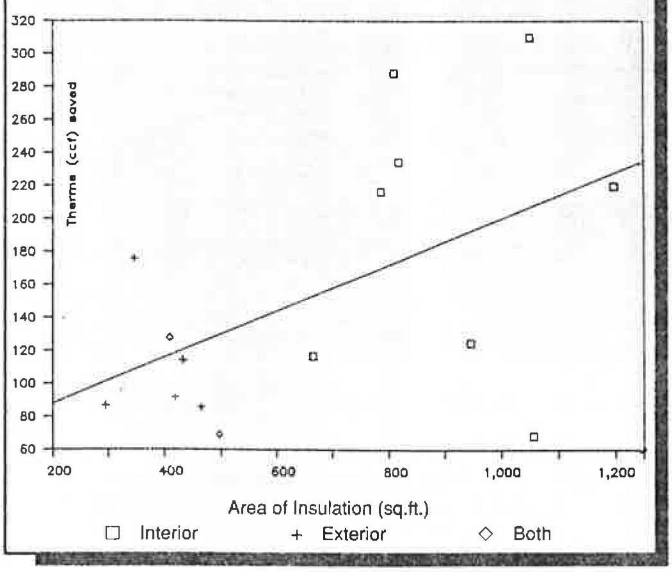
The choice between insulation methods depends on several factors. Interior insulation is usually recommended when a finished basement space is desired, when the retrofit work must be done in winter, or when landscaping must not be disturbed. Exterior insulation is recommended when the basement is already finished, when cracks or leaks need to be repaired on the exterior wall, or when frost heaving (freezing soil, which may move or crack foundations) is possible—generally in wet, clay soils.[4]

Table 1. Foundation Insulation Savings

	Average Therms Saved	Average Percent Saved	Space Heat Percent Saved	Therms Saved/ft²
All Cases (n=15)	155	12.5%	19.2%	0.24
Interior Insulation (n=8)	197	15.0%	23.1%	0.22
Exterior Insulation (n=5)	111	10.1%	15.5%	0.29

Minneapolis Energy Office measured these savings in single-family homes that had been retrofitted only with foundation insulation.

Figure 1. Area of Insulation vs. Therms Saved
Regression line added



Measured Savings from Retrofits

The results from the savings analysis are listed in table 1. The total savings from all cases averaged 155 therms/year, or 12.5% of total annual consumption, which corresponds to about a 19% reduction in space-heating use. Both the absolute and percentage savings from interior jobs were much higher than the savings from exterior jobs, which can be explained by the following factors:

1) Interior insulation covers the entire height of the basement wall, while exterior insulation covers only the top four feet. The average area covered by the interior jobs (915 sq.ft.) was 2.3 times greater than that covered by exterior jobs (391 sq.ft.). Because soil acts as insulation, the greatest part of savings from foundation insulation comes from covering the above- and near-grade portions of the basement wall. So the absolute savings are not twice as great, but only 77% greater for interior insulation.

2) The interior jobs had better coverage of the basement perimeter (95% vs. 88%). Obstacles encountered outside, such as driveways and steps, could not be covered or moved as easily as interior obstacles, such as pipes and wiring.

3) By coincidence, the houses with interior insulation were larger than those receiving exterior insulation. Previous studies have shown that house size is a fairly good predictor of gas use and that the higher the initial gas use, the greater retrofit savings will be.[5] We found a significant relationship between therms saved and area of insulation, but as figure 1 shows, there is a lot of variation in savings as a function of insulation area.

Is It a Home Improvement or a Retrofit?

While the savings achieved by foundation insulation were high, the costs were also high. So the median payback period for all cases was about 19 years (see table 2), which is twice as long as other retrofits typically considered cost-effective. The median payback for interior cases was 16 years and for exterior cases was 21 years. Before writing off the measure, though, consider these factors:

Table 2. Retrofit Payback Times

	Average Annual Savings	Average Retrofit Cost	Median Payback (Years)
All Cases	$85	$1,533	19
Interior Insulation	$109	$1,821	16
Exterior Insulation	$61	$1,170	21

Insulation applied to the inside of the foundation had a quicker payback than the exterior method.

1) The cost in interior insulation included the installation of gypsum board, which by itself is not an energy improvement. While the cost of finishing a wall is relatively high (up to $1/sq.ft.), the marginal energy savings from it are relatively low, since gypsum has an R-value of about 0.45. If the costs associated with this finishing layer are taken out of the total cost, **the retrofit has a simple payback of 8.3 years.**

2) A very desirable by-product of interior foundation insulation with gypsum board is a finished and more comfortable basement space. In the study houses, the cost of adding the basement floor area to the home's living area was $2.40/sq.ft., compared with estimates of $50 to $70/sq.ft. for new construction. Homeowner surveys found that, of those people who insulated on the interior, 92% did so to create more living space and half chose the interior method because they wanted to finish their base-

ments at the same time. If the homeowner is going to finish the basement anyway, even the cost of the stud wall should be considered a home improvement, rather than an energy retrofit, further shortening the payback period.

3) Eighty-eight percent of the study homeowners reported that, even though they did not add any heat to the basement, their basement temperatures were 5–15°F warmer after the work was done. Modeling studies[6] have shown that savings would be maximized by keeping the basement as cold as possible after installing foundation insulation by insulating all heating pipes and ducts running through the basement. Higher temperatures made the homeowners happy, since they made the basement more comfortable, but they also had the effect of lowering savings somewhat.

4) Only about three-quarters of the energy savings predicted by Residential Conservation Service (RCS) calculations were realized. The RCS prediction formula is: ΔU (change in conductivity) x area x heating cost factor. One reason savings didn't reach predictions is the warming effect discussed above, in which higher temperatures near the wall surface increase the driving force for conductive heat loss through the walls. Another reason is that the job installations were probably not perfect. The insulation may not have filled the framed wall completely, may have been improperly matted or folded, or may have been compromised by obstructions. Any gap between insulation and an uneven wall surface can produce convective air flows that degrade the performance of the insulation dramatically. Considering the difficulties in trying to completely seal a basement wall, the ratio of estimated to predicted savings was reasonable, but could probably be improved.

Problems with Foundation Insulation

The homeowner surveys revealed two potential problem areas. Among the group of homes with exterior insulation, two-thirds reported that the cement-based finish that had been applied to the rigid board had peeled or cracked. More durable materials may be needed.

Second, 20% of the study sample reported moisture problems in the basement after installation. Half of these were due to improper backfilling on exterior jobs, which was easily fixed. The other half were due to increased mildew or seepage in basements with interior insulation, which is a much more serious problem. It may be that, in some cases, the insulation traps water that was previously evaporating into the basement. Water can degrade fiberglass insulation so badly that it becomes a heat conductor. More field measurements are needed to determine conditions that might lead to this problem and to suggest possible solutions.

More Research to Come

In 1987, several researchers in the Twin Cities began the Joint Foundation Insulation Study.[7] The study is currently monitoring 20 occupied single-family houses for a year before and after retrofitting with foundation insulation. The researchers are using both interior and exterior methods and taking special care to insure consistency and quality control both in construction and data collection. Retrofits were done in the summer of 1988, and results will be available in the fall of 1989. Data are being collected on energy end uses, basement temperatures, and moisture levels within the insulation structure and surrounding soil. This research should give a much clearer picture of factors influencing the performance and cost-effectiveness of foundation insulation as a retrofit.

Improving Cost-Effectiveness

Here is a summary of suggestions for cutting the costs or enhancing the performance of foundation insulation retrofits:

- For exterior jobs, insulate to grade only. Many low-income weatherization programs around the country do this already. Savings are lower, but costs are much lower because no one needs to dig and backfill a trench. This modification is useful only if the building has a significant area of basement wall above grade.
- For interior jobs, eliminate the addition of gypsum board, and either install a fire-resistant polyethylene barrier or use batts with low-flame-spread facing. This would create a payback period of about eight years.

Table 3. Optimum Amount of Insulation

Location	Minneapolis		Boston		Atlanta	
Energy costs[1]	medium	high	medium	high	medium	high
Deep basement	R-15	R-20	R-10	R-15	R-5	R-10
Shallow basement	R-15	R-20	R-10	R-15	R-10	R-10
Crawl space[2]	R-10	R-20	R-5	R-5	R-5	R-5
Slab on grade	R-5	R-10	R-5	R-10	R-5	R-5

1. **Medium energy costs:** gas heat=$0.561/therm
electric heat=$0.076/kWh
High energy costs: gas heat=$0.842/therm
electric heat=$0.114/kWh
2. Insulation placed down inside wall and four feet out from perimeter.

Source: *Building Foundation Design Handbook.* See note 7.

Charts like this can be found in a new handbook from Oak Ridge National Laboratory, *Building Foundation Design Handbook.* It has calculated the economics of foundation insulation based on modeling studies. This chart gives an idea of the amount of insulation that will be cost-effective in various climates.

- Use higher R-values. The marginal cost of installing more insulation may be more than offset by higher savings. The Joint Foundation Study used an interior method of compressing R-19 batts into a 2" by 4" stud wall, which produces an effective insulation value of R-15,[8] and also eliminates convective air currents within the wall structure. (See table 3 for the limits to the cost-effectiveness of higher R-values.)

Foundation Insulation in New Construction

The economics of foundation insulation as a component of new construction differ substantially from

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State Building Codes

While many states have code requirements for above-grade foundation insulation, the following 15 states also have below-grade codes:

Alaska	U-0.066-0.059, full wall insulation
Delaware	U-0.190 single family; 0.295 multifamily
Idaho	R-5, if floor is uninsulated
Illinois	U-0.215-0.170 low-rise; 0.315-0.255 three stories and over
Indiana	U-0.19, 0.18, 0.17, depending on climate zone
Maine	R-10, to frost line
Massachusetts	U-0.08
Minnesota	R-5 entire wall, R-10 to frost line
New Hampshire	U-0.20 south, 0.18 north to 2' below grade
New York	U-0.09 2' to 7' below grade
North Carolina	U-0.17 to 1' below grade or top of footing
Oregon	R-11 to 1' below grade
Pennsylvania	R-10
Washington	U-0.203 (0.144 for electric resistance heat)
Wisconsin	U-0.20 to 3' below grade or top of footing

U-values given are maximum heat conductance values allowed for foundations for each particular state listed.

Source: *Directory and Compilation of Technical and Administrative Requirements in Energy Codes for New Building Construction Used Within the United States*. National Conference for States on Building Codes and Standards (NCSBCS). For more information on building codes in general or for foundation in particular, contact Marla McIntyre, Director of Communications, NCSBCS, 481 Carlisle Dr., Herndon, VA 22070. Tel: 703-437-0100.

retrofit foundation insulation, since insulation is less costly to install during building construction. While measured data do not exist yet, computer modeling studies[9] have estimated the cost-effectiveness of foundation insulation in new residential buildings. Many insulation configurations have been simulated for full basements, crawl spaces, and slab-on-grade foundations in many cities representing major climatic regions in the United States.

For all foundation types, some insulation was calculated as cost-effective in all but the warmest climates. For example, in fully conditioned deep basements (such as those in the Minneapolis study), R-10 to R-19 full-wall insulation was economically justified in most cities. In slab-on-grade foundations, R-5 insulation was justified in most locales.

These economic analyses are based on 30-year life-cycle costs and medium future fuel price levels. (The projections considered "medium" include electricity costs at $104/million Btu and gas at $40/million Btu by the year 2010.) While the optimal levels of insulation as determined by the computer models are sensitive to fuel prices and construction practices, the first increments (up to R-5) of insulation are the most cost-effective under all conditions.

The assumptions about construction costs are that exterior insulation costs $1.64/sq.ft., compared to $2.95 in the Minneapolis test homes, and that interior insulation costs $1.57/sq.ft., compared to $2.00 in the tests. The cost without gypsum board was assumed to be $0.81/sq.ft. Given these differences in unit costs, it is easy to see why the models forecast that foundation insulation is a cost-effective element in new construction.

In response to the technical guidelines derived from this type of research, several states have incorporated foundation insulation into their current building codes (see box). One problem with these codes, though, is that builders may not follow them. Inspectors may be more concerned with safety and fire codes than energy codes, and this emphasis allows a gap between the rules and their implementation. Several states have made attempts to educate builders and code officials about energy codes and their benefits, but more work is needed in this area.

As energy becomes more scarce and more costly, future efforts to maximize the energy efficiency of buildings will need to move to the next level of investment in conservation. Measures that have long payback periods today may have a much shorter payback tomorrow. It is reasonable to expect foundation insulation to become a common procedure in new and existing buildings when fuel prices rise. ■

Endnotes

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3. PRISM results may have some error due to weather extremes and the fact that basement temperatures rise as a result of insulating the foundation. Unfortunately, present data cannot address this issue. M.F. Fels, 1983. The PRInceton Scorekeeping Method: an Introduction. Center for Energy and Environmental Studies Report No. 163. Princeton University: Princeton, NJ.
4. For construction details, see Basement Insulation. Government of Alberta Energy Department, Energy Conservation Branch, 2nd Floor, 10010 106th St., Edmonton, Alberta T5J3L8.
5. M.J. Hewett, T.S. Dunsworth, T.A. Miller, M.J. Koehler, 1986. Measured vs. Predicted Savings from Single Retrofits: A Sample Study, Energy and Buildings, 9 (1986) 65-73.
6. K. Labs, J.C. Carmody, R.L. Sterling, L.S. Shen, Y.J. Huang, and D.S. Parker, 1988. Building Foundation Design Handbook, Report 86-72143/1, Oak Ridge, TN: Oak Ridge National Laboratory. Also available through the Underground Space Center, University of Minnesota, Minneapolis, MN.
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8. For more information on R-values of compressed fiber-glass batts, see Energy Design Update, Oct. 1985, pp. 4-6.
9. See Building Foundation Design Handbook cited in note 4. See also J.E. Christian and W.R. Strzepek, 1987, Procedure for Determining the Optimum Foundation Insulation Levels for New, Low-Rise Residential Buildings, ASHRAE Transactions, Vol. 93, Pt. 1.