Thermal mass has its place, but R value is the more efficient

By Martin Harris

A recent letter to *Backwoods Home* asked why the construction industry focuses on R values in measuring the insulating performance of building materials. In the writer's opinion, M values deserve equal consideration. He's right, of course.

R & M definitions

R values (R stands for "resistance," meaning resistance to heat transfer through a given material) get more attention because they're the new kid on the block, historically speaking. But for most of the long history of this industry, people who wanted to heat or cool their building used M values (M stands for "mass," meaning the ability of a given amount of a construction material to store heat) because materials with high R values hadn't yet been invented.

New England, with its winter cold and summer heat, happened to be settled by an inventive bunch of ex-Europeans at a time when technology was exploding. With a standard of living that rose fairly steadily through the 18th and 19th centuries, it's no accident that folks here were experimenting with metal stoves and brick insulation in the walls of their wood-frame buildings, with spring-fed milk coolers and sawdust in the walls of their ice-storage sheds, with air-over-ice cooling systems and earth-set barns, and with creating Yankee innovations that caught on nationwide.

By the 20th century, though, the fountainhead of heat-control innovation had moved elsewhere. Neither fiberglass nor mineral wool, electric storage heat (using bricks for M value), nor super-insulated housing (based on super-high R-values) were invented here. What New Englanders did was pioneer the transition from M value to R value in energy management, and it shows up today in the way early 19th century farmhouses were insulated with brick, while only a few decades later builders shifted to sawdust or newspaper, even bunched hay or seaweed.

The same experimentation was taking place in Europe over the same time period, as builders there also came to realize that "empty" air is a better insulating material than "solid" masonry. Ideas like punching dozens of little core holes in brick, or "popcorning" little pellets of clay for use as a pour-type insulating material, came from Prussia and Lithuania, former members of the economically innovative Hanseatic League, and by the 18th century these same communities were quietly innovating in construction techniques as well.

Technological innovations

Such devices don't work too well, however, and were rapidly supplanted when researchers in England and America invented mineral wool and then fiberglass, and even more recently a variety of tongue-twister foam-type chemicals of extraordinary heat-transfer resisting capabilities.

These inventions were, in fact, so extraordinarily effective, low in cost and high in R value, that people pretty much forgot about M value. Erecting buildings with high mass, thick walls, vaulted ceilings, and so on, was becoming an obsolete, high-cost practice anyway, as lighter framing and panelization techniques were devised, so it's not surprising that, except for a few researchers (and an occasional *Backwoods Home* reader), most people don't even know that the M value concept ever existed.

That's too bad, because it has a real place in construction, and in fact is still used.

Historical examples:

When New Englanders built their classic Cape center-chimney farmhouses two centuries ago, they made the chimneys massive (often nine-feet square at the base) so that the huge mass of masonry would act as a heat sink, absorbing heat from the fireplaces when wood was being burned, re-radiating heat back into the rooms when the fires went out.

Even earlier, Anasazi Indians in the Southwest were doing the same thing. They sized their stone or mud-brick walls and roofs precisely enough to absorb intensive daytime solar heat gain (keeping the interiors cool) and to radiate that stored heat during the chill desert nights (keeping the interiors warm). Walls too thin or thick wouldn't match their mass to the daily solar cycle, and these folks understood that.

Today, innovative builders use rock storage or water storage (both are favorites as high-mass, low-cost, heat-storage materials) to capture daytime heat for nighttime use in greenhouses or residences.

The Trombe wall hit a brief peak of popularity 20 years ago during the first Arab oil crisis: it uses a wall of water or masonry just inside a large window to capture solar energy in a building for subsequent re-use. Operable vents at floor and ceiling allow the occupant, after sundown, to set up a natural airflow withdrawing energy from the high-M wall to keep the building comfortable; during the day the vents remain closed and the wall soaks up the sun's rays. Sophisticated designs include curtains which open during daylight and are closed to prevent heat loss through the window at night.

A hundred years ago, American farmers borrowed a Pennsylvania Dutch barn design concept—the cow stable—as a walk-out basement for dairy management systems that were cool in summer and warm (or at least warmer) in winter. Yes, these designs have ventilation problems, and have since been abandoned, but they use the annual cycle of solar heat stored in the ground just as the later Trombe wall uses the diurnal cycle of solar heat stored in water or masonry. Connecticut settlers used the same principles in their housing even before the Revolution, and today earth-set and earth-sheltered housing is making a real comeback (see *Backwoods Home* Issue #9 on this subject).

These examples illustrate how high-M-value construction materials work: they're very good at absorbing and releasing heat (the opposite of high-R-value materials). If you have periodic sources of excess heat—a fireplace fire, daily sunshine, or annual temperature changes—construction based on high-M-value materials can temporarily store the excess energy for later release.

But not much later: high-M-value materials will give up heat energy as rapidly as they absorb it. If it takes a week to heat up the mass of a farmhouse fireplace, it will likewise take a week for all that heat to go back out into the surrounding rooms. If it takes a day for an Anasazi pueblo to warm up, it will cool down overnight. If it takes half a year for the sun to heat the ground on three sides of your earth-set house, you can draw on that heat for the other half.

Using M with R

If you want to store heat for a longer time than its natural cycle in a high-M container, you'll have to encapsulate it in a high-R material: only materials high in R-value will store heat for long periods of time, which they do by preventing heat transfer to the adjacent environment.

If you don't have periodic sources of excess or free heat, high-M materials will store the energy from whatever you choose to buy and burn and will keep you warm for a while after the fire goes out; but they'll radiate as much to the outside world as to your inside room, and so they are not as efficient performers as they might appear to be.

Given the way the M system works, it's understandable that the heavier materials—water and stone, traditionally—are the best storage media. Lead and the other heavy metals would be even better, but then they're also a lot more expensive. Materials low in mass (almost the same as weight, but technically not quite) are also low in M value: you can't store much heat in a batt of fiberglass.

Logs not so hot

Materials in the mass mid-range, logs for example, aren't particularly good at storing heat, although the log-home industry claims that virtue for them. Logs are better than plywood; but then, if you piled on plywood 8 inches thick, you'd have the same value as an 8-inch log wall. An 8-inch log wall isn't as good, M-wise, as an 8-inch solid masonry wall because it doesn't weigh as much.

And you need a lot of M to equal a little R. It would take about 8 feet of solid concrete to equal the R-value of a typical 2x4 stud wall infilled with fiberglass insulation.

The ground rules

Does it pay, then, to design with M-values in mind? Absolutely. But the ground rules should be observed.

Build your building into the ground to capture free solar heat. Don't think that it's economical to buy heat; put it in the ground under your floor slab, and later withdraw it (unless, of course, you insulate around your heat sink and can buy fuel somewhere at some off-season low price).

Build a Trombe wall to capture daytime solar gain for nighttime use. We'll describe the design in a future article.

Store excess or free heat in water or stone but be careful that you don't spend more on the elaborate valves, pipes, controls, and gadgets of so-called "active" solar than the same investment, if put into insulation or even into the bank at interest, could have gained for you. Unless your primary goal is impressing the neighbors (not unknown, in some parts of the country) spending a thousand on solar panels to capture a ten-spot-worth of annual energy makes sense only when the interest rate on money is less than 1%.

Log construction is not a particularly high-M design option. If you want high-M, you'll have to go to masonry or concrete. If you want high M inside your log cabin, do it with a central chimney. An end-wall chimney will radiate heat to the out-of-doors almost as quickly as you pour it in by operating your fireplace. That's why the old-timers in New England put their chimneys in the centers of their houses, while down in the Carolinas the chimneys are end-wall or even semi-detached from the basic structure.

Dollar for dollar, you'll save more energy by going for high R rather than high M. Exception: you have a supply of nice flat stones and free labor.

If you're going for cooling, you'll accomplish it at lower cost with roofs or shading overhangs than with mass. It's particularly difficult, structurally, to put enough mass overhead to retard a really substantial solar heat problem. That's why, incidentally, earth-set housing is most economically accomplished when the roof is framed and insulated rather than concrete-slabbed and dirt-covered.

Non-monetary values

All of the above explains why I'd focus my search for energy-efficiency in construction in R-value, and I'd use M-value as a sort of supporting player. But that's just my opinion: it's based on a dollar-for-dollar kind of analysis, and doesn't take into account the non-monetary values involved in construction. That's why people in northern and eastern Europe—most of them only a generation or two away from rural village life in wood houses of frame or log design—now consider such construction to be second-rate, impermanent, and somewhat lower class. They would rather freeze—genteelly—during the long northern winters in new concrete or brick buildings.

And that's why Americans, most of whom have discretionary income levels that eastern Europeans can only dream about, likewise base our housing design choices on factors other than the economics of building insulation.

That's as it should be: if you total up all the cash-purchase requirements in the annual family budget, the incremental cost of heat needed because of selecting a less-than-perfect structural insulating system is pretty marginal. And, where firewood or coal come from some backyard source, that cost is even lower.

All of which suggests that it's okay for each of us to select the building design we like without obsessing over insulation levels. After all, if we want to save some serious money, we can do it easier and better by bartering goods and services with neighbors than by avoiding log or stone construction because it isn't quite as energy-efficient as other techniques.

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A BHM Writer's Profile

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