

Residential Building Insulation Systems for Cold Climates

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There are many opinions regarding what constitutes the best insulation system for a wood framed building in a cold climate. Architects, building scientists and builders often have conflicting opinions on issues concerning thickness of insulation, vapor barriers, building wraps, drain planes, cold attics and vented roofs. I would like to summarize some of the current thinking and offer my opinions on these matters:

Wall Insulation Systems.

Type and thickness of insulation: The basic types of insulation are fiberglass, cellulose and foam. Fiberglass is probably the most common and is usually applied as “batts” of insulation, pressed between studs.

Most buildings scientists believe that fiberglass provides a poor barrier to air leakage, and convective flow of air through a wall assembly short circuits the insulation and reduces its effective R-value. It also allows moist air to enter the wall cavity. In cold climates this air will drop below the dew point for many hours of the year, resulting in condensation in the wall assembly. Eventually this can lead to mold and decay of the structure, both very undesirable conditions.

To resist air and moisture flow into wall assemblies, the practice of installing a polyethylene “vapor barrier” was adopted. It was eventually discovered that unless this vapor barrier was very carefully installed and sealed (particularly around electrical boxes, wall-floor junctions, and windows) it did not eliminate the moisture related problems. Some people believe that the poly-vapor barrier actually traps moisture in the wall.

It has been my opinion for many years that poly vapor barriers are a flawed solution. I think it is impossible to assure that they are properly installed, and in any event, they are peppered with holes from sheetrock screws when the interior finish is installed. Without a proper vapor barrier, a fiberglass-insulated wall is subject to excessive air leakage, and condensation, and is not a good choice.

One possible solution to the moisture problem is to add rigid insulation to the outside of the sheathing. In addition to increasing the R-value of the wall, the foam insulation has the effect of increasing the temperature inside the wall cavity, thus reducing the number of hours of potential condensation. The thicker the foam layer is, the less potential for condensation. One drawback of this system is that it adds to the cost of the project.

One solution is to increase the thickness of the foam layer sufficient to provide all the necessary R-value (typically R-19, or 2-1/2” of polyisocyanurate foam) and delete the fiberglass altogether. This approach has been used for years by “post-and-beam” builders who apply

stressed skin insulation systems to the outside of their buildings. I think it is a great system. It is virtually airtight, and solves the moisture problem. However, it involves construction details that are not common in stick frame buildings and it comes at a higher cost.

Many building scientists have recently begun to advocate dense-pack cellulose as an alternative to fiberglass insulation. The rationale is that cellulose is much more resistant to airflow than fiberglass, resulting in a tighter building. Cellulose is also favored because it is a recycled material, and because it is competitive in cost with fiberglass.

Unfortunately, I do not believe that the cellulose solution necessarily solves the problem of moisture condensation in the wall cavity because it also relies on a perfect vapor barrier, which does not exist. The addition of foam board to the outside of the wall may mitigate the problem, but it adds expense as previously discussed.

The application of sprayed-in-place foam between the studs is another insulation system that is advocated by many building scientists. The foam is sprayed between the studs in a thickness necessary to achieve the desired R-value, typically 2-1/2 to 3 inches when using high-density foam. The foam expands to fill all the cracks resulting in very low infiltration. The foam is also very impermeable to moisture, providing an effective solution to the moisture problem. This system has the advantage of not requiring much modification to the construction sequence. It eliminates the need for a vapor barrier, and there is room left in the stud cavity for wiring. Its disadvantage is that it is considerably more expensive than fiberglass or cellulose – four times as expensive according to one installer.

I like this system a lot. I think it results in a very tight building and I think it effectively eliminates moisture problems and the associated potential for mold and decay. It is probably not as ecological material as cellulose, and there is potential for toxic fumes should there be a fire, but in balance I think it is one of the best ways to insulate a building.

Building scientists strongly advocate the incorporation of a “drain-plane” in all exterior wall construction. A drain-plane is a gap between the sheathing and the exterior siding that prevents water from entering the wall from the outside, permits a way for water to drain out of the wall, and allows the back faced of the clapboards or shingles to dry. A building wrap such as Tyvek® or felt paper is applied to the sheathing as a barrier to water. A space is created by applying strapping to the exterior sheathing to hold the siding off the wall. There are also some specialty products specifically developed to create this drainage gap. It is recommended that wood siding be primed on the back side before it is installed.

In my opinion, it is very important to install a drain-plane on all walls. This extends the life of the siding, increases paint retention, and prevents moisture from entering the wall insulation. It is absolutely critical if the insulation is fiberglass or cellulose.

Roof Insulation Systems.

The first decision is whether to insulate the attic floor to create a “cold attic” or to insulate between the roof trusses. Cold attics have been the system of choice for many years. This is the simplest system, and involves the application of 12” fiberglass batts or blown-in cellulose on the bottom cord of the trusses, and the addition of soffit vents, ridge vents or gable vents to keep the attic cold. It is critically important to keep the attic cold in order to prevent ice dams. If the attic is warm, the heat melts snow on the roof which refreezes near the eaves to cause ice dams. Various “solutions” such as metal flashing at the bottom of the roof, bituthane roofing materials, or electric heat tapes have been employed to eliminate ice dams.

The problem is that the so-called cold attic is very difficult to achieve. Warm air leaks into the attic through the fiberglass (around attic hatches, chimney, and wall-roof junctions) short circuiting the insulation. Not only does this cause ice dams, but also represents a major waste of energy. I have investigated a number of apparently well-constructed ceilings where the effective U-value of R-38 insulation was reduced to R-4 by air leakage. If HVAC ductwork is located in the attic, the problem is further aggravated and the efficiency of the mechanical requirement is reduced. In my opinion, insulation of the bottom cord of the truss to create a cold attic is a poor choice.

An alternative approach is to insulate between the rafters or on top of the roof deck. In these cases, the attic becomes part of the heated space. Insulation between the rafters with fiberglass batts or cellulose raises some of the same concerns as when used as wall insulation. Moisture passing through the insulation will condense in the outer edge of the insulation or on the inside of the roof sheathing. The solution to this problem has been to leave a gap between the top of the insulation and the sheathing, and to provide vents at the soffit and the ridge to allow outdoor air to carry away the moisture. The problem is that this is also a path for air infiltration through the insulation, which reduces the effectiveness of the insulation. Roof valleys also present challenges to this approach.

I think insulation between the rafters with fiberglass insulation is a poor approach, and insulation with cellulose is not much better. Both rely on a near perfect air/moisture barrier which I think is very difficult to achieve.

Spraying foam between rafters in a manner similar to that used in the walls, and has the same advantages. Since the foam is impermeable to moisture, it is not necessary to vent the roof and the foam is applied directly to the back of the sheathing filling the rafters sufficiently to achieve the desired R-value – usually R-30 or R-38. This system will require the bottom of the rafter be covered with fire-rated sheetrock.

In my opinion, this is one of the best ways to insulate the roof. It solves the infiltration and moisture problems. It also provides a warm attic, which is useful for storage and suitable for HVAC equipment and ductwork. As with wall systems, it costs more, but it works.

One final approach is to install rigid insulation on top of the roof deck. This approach is used in most of the post-and-beam houses. It is possible to use prefabricated stressed-skin panels

consisting of foam insulation sandwiched between sheathing and sheetrock, or it is possible to fabricate this system on site. This system has the advantage of covering the rafters as well as the space between the rafters. This system does not require fire-rated sheetrock on the inside of the rafters.

This is probably the very best system as it provides a thermal break over the rafters. However, it may be more costly than foaming between the rafters, particularly if a contractor will be on site to foam the walls. If this system is field fabricated, it is critical that there are no gaps between adjoining rigid board panels. Rigid board should be applied in two staggered layers, and any gaps should be filled with spray foam.

The Bottom Line.

I don't like fiberglass insulation systems at all. I think they result in buildings with higher than necessary infiltration and heat loss, and I think they contribute to moisture related decay and mold. I would never recommend this system for insulating walls or roofs. The so-called "cold attic" is a myth and should never be attempted. While cellulose is a more environmentally friendly material than fiberglass, or foam, and while it results in better resistance to infiltration, I think it is still possibly subject to moisture related problems and could provide a substrate for mold under certain conditions such as when rooms are maintained at high humidity levels. Technically, I think foam applied to the outside of the structure, such as the "stressed skin" panels used on the walls and roof of post-and-beam buildings is the best approach. This approach could be applied to stick-framed building as well, but requires different detailing around windows and at soffits and so may be expensive to implement. The spray in place high-density foam in the walls and rafters would also solve the moisture and infiltration problems and result in a good insulation system.

I would also like to offer an opinion on insulation thickness for foam insulation systems. Current practice and current codes require R-19 walls and R-38 flat ceilings or R-30 sloped ceilings. These insulation values were derived from life cycle cost analysis based on fiberglass costs and R-values. The reason that more insulation is located in the ceiling than the walls is mostly because it is cheap to put in the ceiling and expensive to put in a thicker wall, and not because there is more heat loss through the roof or ceiling. The economic analysis would be different for foam insulation. I think the code minimum of R-30 for sloped ceilings is sufficient and that any additional insulation on the roof would have a long payback. It is probably acceptable to stick with R-19 in the walls, but it would not be crazy to increase this to R-25.

I want to finish my thoughts by focusing on mold. Mold spores can create toxins that can cause serious illnesses in certain individuals. Mold requires two things to grow: moisture and cellulose. It is common to see black mold on the damp cardboard (cellulose) surface of sheetrock in basements. If we looked, we might also see it on the inside of the sheetrock in damp walls that are built without a proper drain plane. One would think it might find cellulose insulation a suitable substrate if the insulation was damp.

It is not clear exactly what circumstances would lead to mold in a conventionally built wall with fiberglass or cellulose insulation. Clearly, the level of moisture in the house would play a major factor. A very tight house, or a house with a lot of plants, or a house that was humidified would be more susceptible than one that was fairly leaky. We know from experience that houses with a relative humidity greater than 30 or 40% in winter often experience condensation problems. The safe thing to do is to prevent moisture from entering wall and roof systems by employing drain planes and using foam insulation systems.