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Spray-in-Place Polyurethane Foam Insulation

An opinion paper by:
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Expanding spray-in-place foam insulation products such as those based on a polyurethane formulation have several beneficial aspects over other forms of insulation. Spray foam insulation currently costs more than alternative insulation products, but this additional up-front cost can be overcome when the other benefits of spray foam are utilized and realized. These aspects include benefits associated with increased structural/strength properties, enhanced thermal insulation capabilities, and reduced air infiltration properties.

Structural benefits: Clemson University has been researching the use of spray foam as an enhanced attachment system for roofing. This research centers on how to retrofit or construct buildings to be more resistant to hurricane and other high wind events. Clemson's research shows that spray foam can significantly improve the attachment of roof sheathing to trusses and rafters, similar to the way construction adhesives help bond a floor system together. In a retrofit case, foam can be sprayed on one or both sides of the sheathing/rafter intersection from inside the finished roof. In new construction, spray foam can be applied to the entire roof system. The spray foam makes a significantly stronger roof than either nails or screws alone. More information on this research is available from Clemson University's Civil Engineering Department, or the 113 Calhoun St Project in Charleston, SC.

Thermal and air benefits: A second aspect of spray foam is the enhanced thermal insulation characteristics. The stated R-value, or thermal resistance value, of insulation is measured under laboratory conditions. Real-life in-use R-values are quite different. An R-13 rated insulation batt installed improperly may only provide R-9. Whole wall R-values may be even less because of voids, wood, headers, etc. in the wall. Spray foam can provide a higher whole-wall R-value because of its ability to better fill wall cavities around electrical, plumbing, and other obstructions within the wall. The Oak Ridge National Lab has tested several whole-wall R-values for various wall/insulation combinations. Some of their results have been published in publications such as Energy Design Update, and should be available on their web site soon.

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The R-value of an insulation system also depends upon the lack of air movement through the insulation. Most insulation products use entrapped air as a barrier to heat transfer. Therefore, to get a high R-value, air cannot move within or through the insulation.

In a whole-house situation, part of the energy use is in infiltration air. Air flow retarder products such as house wraps were developed to reduce the amount of infiltration air. These air barriers help reduce infiltration as well as air movement through the insulation.

Typical loose fill or batt insulation works well if installed correctly, and if installed in conjunction with an air barrier. Good installation is difficult to do, however. The insulation is often packed too tight or too loose, cut too short or too long, gapped around plumbing and wiring, or left out because of access problems.

Spray foams claim a couple benefits. First, they fill gaps and voids better. Second, they perform well as air flow retarders. The result is a higher in-the-wall R-value. Infiltration is also reduced, so that component of a building's energy use is reduced. Both of these benefits result in raising the "effective" R-value of spray foam when compared to typically installed loose fill or batt insulation.

Spray foam products must still be sprayed correctly, and dense-pack blown cellulose can make some of the same claims. Spray foam is also self-supporting, which enables its use on the underside of roofs and floors.

Roof Benefits: Insulating the underside of a roof rather than a ceiling creates many other benefits as well. Historically, we ventilated roofs in an attempt to prevent moisture problems and reduce heat build-up.

Current research shows that much of the moisture in attics comes from damp basements or crawl spaces, as well as from the living space. Research also shows that if we address crawl space, basement, attic and living space moisture, we do not need to ventilate an attic. In fact, by ventilating an attic, we can often make a moisture problem worse.

Attic moisture problems are a result of moisture condensing on cold roof surfaces. Adding more vents causes the attic to be cooler, especially at night, which causes more condensation to form on the underside of the cold roof. Cutting a hole in the roof causes a bigger hole in the top of our "chimney", which makes the "chimney" draw better, pulling even more moisture upward. I have not seen any attic moisture problems solved by adding attic ventilation, with the exception of ice damming. (Ice damming is a "warm" attic phenomenon, and can better be addressed by reducing the amount of heat leaking into the attic.) Unfortunately, the building codes haven't kept up.

Ventilation to reduce summer heat build up in an attic has also been challenged recently by research done at the Florida Solar Research Center and the Building Research Council in Illinois. Much of the heat in an attic is from radiant heat transfer. The hot sheathing radiates heat to the ceiling or other objects in the attic. To cool an attic, outside air is vented through attic or insulation is added to the ceiling to prevent the attic heat from warming the living space. Research has shown that the ventilation rate would have to be quite large to make much difference in an attic temperature. In the summer, the best you could possibly achieve was outside temperature. With a very large fan using lots of energy, you might get close to outside temperatures. In winter, this would result in a colder attic as well.

Ceilings are usually insulated because of the ease of piling up cheap insulation. Recessed lights, outside walls, sloped or tray ceilings and knee walls all create a non-uniform thermal "cap" on the building and result in voids in the insulation. The real-life R-value of an insulated ceiling is very often less than the claimed R-value.

Ducts are often located in the attic, which exposes the coolest/warmest air in the house to the hottest/coldest environment in the house (depending upon the season). This does not create a very energy efficient situation. As much as 10% of the heat or AC can be lost by placing ducts in an unconditioned attic.

From an energy standpoint, ducts and air handlers should be located within the conditioned space. This reduces heat transfer to the outside, and reduces some concern of duct leakage. Recently, building researchers proposed making crawl spaces into unvented, conditioned plenums, which is now accepted by code. More recently, building researchers proposed making attics into conditioned space by eliminating ventilation and insulating the underside of the roof rather than the ceiling. As a building researcher, I fully support both concepts.

A roof system insulated with spray foam reduces energy several ways. Energy loss from ducts located in the attic is essentially eliminated. The top of the building is much tighter resulting in less infiltration and exfiltration, so excess moisture isn't pulled into the attic. Infiltration through the ceiling is also reduced. In addition, the attic temperature is lower, which further reduces energy loads.

In a standard insulation system, ceiling insulation reduces the transfer of heat from the attic to the living space (in the summer). Attic temperatures can often approach 140F during the day. Most of this heat enters the attic space through a multi-step process. First, solar energy warms the shingles and sheathing. The hot sheathing then transfers heat to the rest of the attic through conduction, convection and radiant heat transfer. The 140F temperature of the underside roof surface drives the heat transfer process

By insulating the roof surface with spray foam, the surface temperature exposed to the attic (the temperature driving the heat transfer) is reduced by as much as 40F. Both conduction and convection heat transfer are proportional to a temperature difference, so that heat transfer will be reduced proportional to a drop in surface temperature. Radiant heat transfer, though, is proportional the 4^{th} power of the temperature difference. The reduction in radiant heat transfer resulting from an insulated roof can easily exceed conduction and convection reductions.

The benefits of including the attic in the insulated space are:

- Duct leakage and heat loss/gain from ducts is much less of an issue.
- Air sealing is easier in the roof that in the ceiling.
- Dust and loose insulation are less likely to migrate down to the living space.
- Tests show energy costs are lower when the attic is sealed.

Further information is available from ASHRAE (8700-527-4723) in a publication titled "Vented and Sealed Attics in Hot Climates".

Crawl Spaces Benefits: Batt insulation is usually installed between the floor joists over a crawl space foundation. Problems associated with this installation technique include incomplete thermal barriers from obstructions such as wiring and plumbing, ductwork, and narrow or wide joist spacing. Batts are often compressed during installation due to the use of wire insulation hangers. Open web floor trusses create additional problems in that the open webs create pathways for air to move around the batts. During the summer, warm humid air can flow around the batts and create condensation, mold and decay problems in the floor system. In my opinion, open web floor trusses are impossible to adequately insulate with batts.

Spray foam circumvents floor insulation problems through its ability to completely fill voids and open spaces. Areas around wiring and plumbing as well as open webs of floor trusses can be completely filled, resulting in a complete, essentially uniform thermal barrier on the floor. Spray foam will also create an effective air flow retarder layer on the floor, which will reduce the house air by crawl space air.

In my opinion, spray foam insulation is a superior insulation product that overcomes several disadvantages of other insulation products. Spray foam can provide a more uniform, consistent thermal barrier as well as provide air flow retarder functions. To best obtain spray foam's potential benefits, and overcome it's higher initial costs, spray foam should be used in a systems approach to creating a better building. In a roof application, spray foam will increase the structure's ability to handle high winds as well as bring the attic into the conditioned space. A roof application of spray foam will reduce infiltration and reduce ceiling heat transfer and duct losses. Wall and floor applications will also create better thermal and air barriers, and make better use of engineered products. Spray foam insulation can result in less conductive, convective and radiant heat transfer, lower infiltration rates, less duct losses, a more structurally sound building and can result in significantly smaller-sized heating and cooling systems and better comfort levels for the occupants.