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Spray foam in warm, humid climates

An opinion paper

by

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Spray-in-place polyisocyanurate (polyurethane) foam is a high performance building material. Spray foam is primarily used as an insulation material. When installed, the foam expands in place and fills in around plumbing, wiring and other obstructions in the framing. For this reason alone, spray foam often outperforms batt insulation. Other characteristics of the foam, as described below, provide additional benefits.

Spray foam used in building construction typically comes in two forms: low-density or open-cell foam, and high density, closed cell foam. Because of the different physical properties and make up, these two foams cannot routinely be interchanged. Open-cell foam is better in some situations than closed-cell foam and vice versa.

<u>Moisture permeability:</u> Open-cell foam is described as being somewhat moisture permeable. In other words, some water vapor can move through the foam under the right conditions. By contrast, closed-cell foam is said to be moisture impermeable, or water proof. Water will not readily pass through this foam. By comparison, fiberglass and cellulose insulation are both considered highly moisture permeable. The kraft facing on some batt insulation has approximately the same moisture permeability as open-cell foam, but when installed improperly, moisture will move around or even through this facing.

<u>Air permeability:</u> Both foams are essentially air-impermeable. (And so is plywood, OSB and drywall.) At much less thickness than typically installed in buildings, no appreciable air will move through either foam. By comparison, air will readily move through fiberglass batts and blown-in insulation. High density systems such as "blown in blanket" fiberglass and cellulose insulations are less air permeable than batts, but still much more air permeable than spray foams.

For a material to be called "air impermeable", the maximum leakage rate at 75 Pascals (Pa) pressure difference is 0.02 liters per second per square meter. (0.02 L/s-m2) The air permeance of insulation material is measured using ASTM E 283 as listed in section R806.4.2 of the 2006 IRC (International Residential Code). ASTM E 283 is the Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen. For comparison, the air permeance of 3/8" plywood sheathing is 0.0067 L/s*m2 @ 75 Pa. Some open-cell foam measures at 0.009 L/s*m2 @ 75 Pa at 3.5 inches thick. Closed-cell foam is less permeable.

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But what are the implications? From a simple approach, a house with walls measuring 8 ft high by 24 ft wide by 60 ft long might have an insulated wall area of 1200 square ft (or maybe 114 sq meters.) Air will leak in only half that area (because it leaks out the other half). Over an hour, about 65 cubic feet will leak into this house at 0.009 L/s-m2. (And that is when the wind is blowing 25 miles per hour. So we are realistically leaking maybe a third of that under normal conditions.) We want leakage in a house to be about 1/3 air changes per hour, or in our example house, 3840 cubic feet per hour. Either open-cell or closed-cell foam will make air leakage through the foam insignificant.

Heat flow: One measure of the performance of insulation is its resistance to heat flow. This resistance is stated in a number called the "R" value. Building codes typically require R-13 insulation in walls. As such, fiberglass batts are rated at R-13 at a thickness of 3 ½", which is the thickness of a typical wall. (Or is it the other way around? In reality, fiberglass at a thickness of 3 ½" can't economically be manufactured much better than R-13, so the codes have really been written to deal with this limitation.) Open-cell foam has a similar R-value of near 3.6 per inch. For a 3 ½" installation, this would be R-12.6 or a nominal R-13. For closed-cell foam, its R-value is closer to 7 per inch. When installed in walls, only 1 ½ to two inches of closed cell are commonly used, providing an R-value near R-13.

R-value is a measurement of the resistance to heat flow through a substance, or what is scientifically called conduction heat transfer. In this case, the substance is the insulation. Two other methods of heat transfer are encountered in buildings. One deals with air movement, and is called convection heat transfer. Air containing heat can move through porous material and carry that heat with it. Since fiberglass and cellulose are somewhat porous to air movement (air permeable), some heat can move into or out of a building with air movement through the insulation.

Another type of air-flow heat transfer that occurs in porous insulation is called "convective looping" where air moves just within the insulation rather than through the insulation from one side to the other. This looping is caused by the phenomenon that warm air tends to rise, and cold air falls. Temperature differences between upper parts of walls and lower parts, or an inside surface versus an outside wall surface can cause this form of heat transfer. Air impermeable insulations such as the spray foams eliminate convective heat transfer. This characteristic allows R-13 of spray foam to outperform R-13 of fiberglass or cellulose insulation.

A third form of heat transfer is the flow of radiant energy. A hot surface can transfer energy to a colder surface across an open space. This mode of heat transfer can be felt when standing in front of a fire. No conduction is occurring because you are not touching the fire. Convective heat transfer is not causing your front to get warm while your back stays cool because the heated air typically goes up the chimney. Energy "radiating" from the fire moves through the space to warm you and other objects and surfaces around you. Foams as well as other insulations can affect radiant heat flow when placed in the proper location. But foams can be used in places and under circumstances where other insulations cannot be used, and can greatly reduce radiant heat transfer.

Heat, air and moisture flow: In building construction, controlling the flow of heat, air and moisture are important. Heat flow is typically controlled by insulation. Controlling heat flow is important to control indoor comfort and energy costs. A secondary, but important, consideration in controlling heat flow is to control temperatures of surfaces in the building envelope. This aspect will be discussed in more detail in following paragraphs.

The control of air flow is important because air contains pollutants, dust, dirt, heat (or cold) and moisture. Air flow control is typically accomplished with caulks, tapes and housewraps. Lots of publications show details and methods of air sealing buildings. Many show how to seal the outside of a building or the inside of a building (such as the air tight drywall system.) These methods are designed to prevent air from getting from one side of a wall to the other through air permeable insulation.

The control of moisture has, until very recently, been pretty well ignored. It happened, but we only dealt with it if we could find a leak. Now that we better understand the relationships between air and water, water and fungi, and concerns with fungi (mold) and health, much of the construction industry is working to address potential issues. In the last several years, the industry has come up with building materials of various moisture permeability such as synthetic roof underlayments and housewraps, "drainage planes," dehumidifiers, "thermidistats," and energy recovery ventilation systems. These materials and systems help keep water out, or help deal with it once it gets in.

Moist air: Two forms of moisture typically affect buildings in warm, humid climates: liquid and vapor. Common liquid water sources are roof and plumbing leaks, leaks around windows and doors, and condensation. Common water vapor sources are air, clothes dryers, bathing and other family activities. In these cases, liquid water is turned into a gas where it can then move freely through planned and unplanned openings in buildings.

Air, as we know it, contains some moisture. A phenomenon with "moist" air is that the amount of moisture the air can hold depends on the temperature of the air. As air is heated, it can hold more moisture. As air is cooled, it can hold less moisture. The amount of moisture air holds is commonly stated as "relative humidity" or the relative amount it is holding compared to the maximum amount it can hold, at that temperature. For example, air at 70 degrees and 50% relative humidity (RH) is holding 50% of the moisture air can hold at 70 degrees. Air at 100% is saturated, and cannot hold any more moisture.

As a hunk of air is cooled, its capacity to hold moisture decreases, so it's RH goes up. If cooled enough, it reaches 100% RH and becomes saturated. If cooled further, the water vapor turns into liquid water; it becomes condensation. (An air conditioner helps dehumidify air because it cools the air below the air's condensation or dew point temperature, and condenses some of the water out of the air.)

Decay fungi need liquid water. Molds and mildews typically need a humidity higher than 80% RH. If plumbing and roof leaks aren't enough to worry about, condensation can also provide the liquid water necessary to cause problems. Even without liquid water, high relative humidity can lead to mold growth.

In buildings, cold surfaces exposed to warm, humid air can result in condensation and high RH. In the winter, inside warm air can leak outward and contact cold exterior materials and condense. In the summer, warm, humid outside air can leak in and condense on or raise the RH near cold air conditioned surfaces.

In South Carolina, the dew point or condensation temperature of outside summer air ranges from about 72F in the Greenville area to near 75F along the coast. If this air leaks into a building cooled by air conditioning below its dew point, condensation, mold and decay are possible. To deal with this possibility, air flow needs to be stopped as much as possible, surfaces need to be kept warm and objects that do get wet need to be able to dry.

Buildings and building materials will get wet. To prevent fungal problems, they must dry quickly. Fireplaces, lack of air conditioning, leaky walls and windows, and a lack of insulation actually helped historic buildings dry relatively quickly. With the advent of tighter buildings, indoor plumbing, air conditioning, and insulation, buildings were exposed to more moisture and to slower drying conditions. Controlling moisture is now more important than ever.

Spray foam's use in building performance: Spray foam is a superior insulating product. It expands as it is installed and fills wall cavities better than batts. Spray foam is not compressed around obstacles or during installation, another way batts lose insulating value. Spray foam does not allow air movement, so air leakage and convective looping do not occur. Both open-cell and closed cell can perform these functions about equally. Both foams provide better insulation, and help keep warm surfaces warmer and cold surfaces colder.

When it comes to addressing moisture, the differences between open-cell and closed-cell foam become important. A simplified, initial difference is that open-cell foam is better suited for use against materials that can be damaged by water, and that closed-cell foam is better suited for use against materials not affected by water.

Even though open-cell foam is considered air impermeable, it is somewhat moisture permeable. Under conditions where warm humid air could contact a very low moisture permeable or very cold surface, sufficient moisture could move through the foam and condense against the surface. Examples of this situation are AC ducts in vented crawl spaces, or walls with vinyl wallpaper. In both situations, moisture cannot pass freely through the system at an acceptable rate and builds up to a detrimental level. The ducts could be coated with closed-cell foam to address the situation since the duct material typically won't be harmed by water, but the walls likely cannot be fixed with closed cell foam. (Vinyl wall paper is bad news in the south, and very intricate details need to be in place to make it work OK.)

In wood frame structures in the south, much of the drying of a building occurs to the inside. For this reason, everything inside the exterior weather layer needs to be somewhat moisture permeable. Open-cell foam works well for this application. Closed cell foam does not. If closed-cell is used inside exterior sheathing, and the sheathing gets wet, it cannot dry fast enough to the outside to prevent problems. The sheathing could rot before any water issues become apparent. The same situation applies to attics: open-cell foam works well applied to the underside of roof sheathing, while closed cell does not. Closed-cell can prevent any water leaks from being apparent until the sheathing has been destroyed.

I have personally witnessed a leak occurring above open-cell foam. Water was sitting on a surface below the foam, and the foam was covered with drips. I actually thought a pipe below the foam had leaked and sprayed water up on the foam. But when I started tracking the leak, I realized the foam was soaked in about an 8-inch diameter area. Digging up through it, I found the leak. Had this been closed-cell foam, it would have taken significantly longer to find the leak.

Closed-cell foam can be used successfully on the outside of a wood frame structure. For instance, closed-cell foam can be applied to the exterior of roof sheathing to create a water-resistant, well insulated roof system. In this case, the foam acts as a water resistant barrier, while the wood sheathing is still able to dry to the inside as necessary. (Note, though, that even in this situation, the foam needs to be protected from the weather with some weather resistant material.)

Closed cell foam can also be used successfully against bricks, rock and concrete work. These items are typically not harmed by water. Closed-cell foam can also be applied to the inside of metal siding and roofing. (Open-cell foam can also be used in these situations in cooling climates.) Against water permeable materials like brick or block, closed-cell foam can be used to provide an interior waterproof coating. This can be beneficial in basements or above grade block foundations where exterior waterproofing is not possible. (In situations where exteriors are sufficiently waterproofed, open-cell foam can be used on the interior of these walls.)

Crawl spaces: Spray foam and crawl spaces can work, but several constraints and issues exist. Conditions in a vented crawl space are typically wetter than outside air. As such, dew points are higher. As a result of these high dew points, decay and fungal issues are prevalent in vented crawl spaces. Floors over crawl spaces need to be protected from crawl space air and moisture. Spray foam can be used to accomplish this, though the penalties can be severe. If open-cell foam (or other moisture permeable insulation) is used to insulate the floor, low inside temperatures and impermeable floor coverings can lead to floor problems. Condensation can occur under vinyl flooring, resulting in fungal growth and decay. Hardwood floors can cup or buckle.

If closed-cell foam is used to insulate the floor over a crawl space, any inside water leaks will necessitate removal of flooring. Water will not be able to drain through the floor into the crawl space, and the sheathing cannot dry to the crawl space. Also, since closed-cell foam is extremely difficult to remove, temporary removal to aid drying and repair is not a feasible option.

In addition to the above problems and issues with insulating floors over crawl spaces, additional affects are likely. Any beams and sections of joists exposed below the foam are not protected from the crawl space environment, and will likely experience mold and decay. Ducts and AC equipment in the crawl space can also experience condensation and other moisture issues.

For these and other reasons, crawl spaces in the southeast should be unvented and semi-conditioned. Here, semi-conditioned means that humidity levels are controlled. Closed cell foam can be used on the inside of foundation walls to insulate and water proof the foundation (though exterior waterproofing is more effective.) Other types of insulation can be used on foundation walls when sufficient waterproofing and air sealing details are provided. With foundation wall insulation, floor insulation becomes unnecessary and even counter productive. Ducts should still be insulated and air tight. As mentioned earlier, closed-cell foam is best for insulating ducts, though under the right crawl space conditions, open-cell foam can perform well.

<u>In summary</u>, spray foam is a high-performance insulation material that also provides other benefits to the building and occupants. Due to its ability to completely fill voids and cavities, and its air and moisture permeability characteristics, spray foam is an efficient material for controlling heat, air and moisture flow in a building. Spray foam is one of the best components for providing the environmental separation critical to making buildings work properly.

Open-cell foam is used on the inside of materials that can be damaged by water. Open-cell is superior in walls and under roof sheathing. Open-cell foam can work well under floors over conditioned crawl spaces. Open-cell foam should not be used against moisture impermeable surfaces that are exposed to high-dew point air (such as ducts), low-permeable floors over humid crawl spaces, or against wet surfaces such as basement walls.

Closed-cell foam is used against metal, brick and masonry. Closed cell foam can also be used effectively on the outside of wood sheathing or other material that has the ability and need to dry to the inside. Closed-cell foam should not be used on the inside of wood materials, or under wood-framed floors.

For more information about the specific product you want to use, contact the manufacturer.