Insulation & R-value: A comparison of insulation materials in building systems.

We constantly use energy to make our environment comfortable. In the winter we use energy to add heat to our homes and in the summer we use energy to remove excess heat. Fighting Mother Nature uses a lot of resources, so making sure that we are as efficient as possible requires good insulation.

Insulation is a material or combination of materials that blocks the transfer of heat from one material to another. In building construction, insulation prevents the transfer of heat from the outside in the summer to the inside of the home or building. In the winter, it works in reverse, preventing the warmth from the inside from transferring to the outside. Quality insulation reduces the amount of energy needed to heat or cool your home and maintain a consistent temperature.

When evaluating R-value claims by manufacturers in advertisements, there are a few points to keep in mind. Not all types of insulation have the same R-value or perform the same. Each has its own distinct advantages and disadvantages. The insulation material characteristics, installation and the wall assembly are some of the most critical factors in evaluating insulation effectiveness.

One characteristic of different insulation materials that few consumers or even insulation contractors fully realize is the effect moisture in the insulation has in reducing its effective R-value. Many of the insulation types listed below and used in most structures are ineffective once they become filled with high levels of moisture. Another characteristic of each insulation type discussed in this document is heat saturation (BTU). Heat saturation is the capacity of a material that when reached limits the material's ability to act as a good insulator.

Low saturation resistance for either of these characteristics limit the insulation's ability to act as a good insulator. To understand how saturation rates work consider the example of placing a sponge under a dripping faucet. Once the sponge becomes fully saturated with water, each additional drop of water that falls on the sponge will cause a drop of water to fall out of the sponge on the other side.

The same effect occurs with heat saturation in all insulation types. When the insulation is fully saturated with heat, for each new unit of heat (BTU) that is absorbed into the wall insulation a BTU of heat penetrates the wall into the structure. Having a high resistance to heat saturation or high heat saturation resistance for a given insulator is of primary importance. Otherwise, once saturated the insulation is basically no longer an effective insulator from heat.

This is often seen in homes with glass batt insulation. On a hot summer day the insulation in the wall cavity and ceiling usually becomes fully saturated with heat energy and the insulation is almost non-effective. The home's air-conditioning units will work all night to reverse the process before another cycle begins. If higher quality insulation materials are used, this cycle typically never begins and heat is unable to enter the home in sizeable enough quantities to significantly raise temperatures inside the structure. This reduces the structure's energy costs significantly.

TRADITIONAL FIBERGLASS INSULATION

The most prevalent insulation in homes is fiberglass batt insulation. This insulation is inexpensive, available everywhere, and simple enough for a do-it-yourself install. Batt insulation is installed in the cavities between the studs in a wood frame wall, and is available with and without a paper backing which acts as a vapor barrier. There are several disadvantages when using batt insulation. It allows air to leak and flow through the wall and over time it can settle or compress, reducing its R-value. It can also serve as a nesting place for rodents and insects. The R-value of this insulation will also decrease as moisture and humidity increases in the wall. If the material becomes wet, and it can hold a great deal of water, it effectively loses its insulative value, and becomes a conductor of heat energy, either into or out of the home. When damp it can also serve as a habitat for mold growth.

New energy guidelines are requiring a layer of continuous insulation, most typically an exterior foam sheathing or panel, in addition to batt insulation in wall cavities, which is then taped or sealed to reduce air leaks. This helps with one negative aspect of this type of insulation, it doesn't address other deficiencies like it's very low saturation resistance for moisture and heat (BTU). It is one of the lowest rated insulation types for heat saturation resistance, thus allowing large amounts of heat into the structure during the summer months.

BLOWN INSULATION (FIBERGLASS AND CELLULOSE)

There are two main types of blown insulation: fiberglass from sand or glass resin or cellulose made from recycled newspapers and other material. The greatest benefit to blown insulation is a much denser coverage of potential air leaks. The insulative capacity of both fiberglass and cellulose is very close, between 3-4 R's per inch. When batts of either material are used they don't fill all the spaces between the studs for walls or ceiling joists in attics. Blowing smaller pieces of this material into an attic space or in walls reduces air infiltration around openings and mechanical installations.

This material is still fully contained between the studs. Not insulating the studs themselves provides clear thermal bridges between the interior and exterior. Typically additional insulation is required on the outside of the home to offset this, adding time and cost. This type of insulation also has an extremely low saturation resistance per inch, meaning it takes very little water to fill up the material. Once the material is saturated, like wet sponge, heat energy flows through the material readily. Once installed it is an effective insulation, but still suffers from the disadvantages of the material itself such as water infiltration, pests, and compaction and low moisture and heat saturation resistance. It should be noted cellulose, though having a low moisture saturation resistance, it does have a much higher heat saturation resistance as long as the attic or wall cavity air is of low humidity. This is not usually the case in cold and moist climates. Cellulose insulation, though manufactured with a fire retardant, once ignited will burn readily.

MINERAL (STONE OR ROCK) WOOL

Stone wool is made from basalt rock and slag a by-product in the manufacturing of steel. This process is fueled by Coke a form of coal with few impurities and a high carbon content. The basalt and slag are heated to more than 1500°F and mixed and whipped forming the stone wool. It is then layered and then heated again with a binder material to form dense batts. The density of the wool makes the material moisture resistant along with the oil added to the fibers added during the manufacturing process.

This type of insulation is the most superior form of batt insulation. It has excellent fire resistance properties since it has a melting point nearing 2,000 F. Rock wool batting provides an R-value of 3.38 per inch of thickness, while blown-in rock wool is 2.75 per inch. Stone wool doesn't shrink over time and maintains its R-value. One of the primary uses for stone wool is as a growth medium for plants and hydroponics. Like all batt insulations, stone wool can also serve as a habitat for mold and for nesting rodents. This is true of all batt style fiber insulation material. Other disadvantages of this material include high cost, low residential availability, environmental impacts of manufacturing, and danger from dust and fibers during installation. Both Stone and rock wool have low moisture and heat saturation resistance.

SPRAY FOAM (ICYNENE) INSULATION

Spray Foam (Icynene) and other professionally applied foams give a very tight seal to the walls, and can be open or closed cell. Open cell foams are permeable to moisture and air, closed cell foams are not. These foams are excellent insulators, but are difficult to apply and require specialized equipment and training. For this reason, they are more costly, and still require a continuous insulation to meet the newer energy codes in wood framed homes. These foams are widely used in attics and as roof insulation in commercial buildings.

Disadvantages of spray foam insulation are mostly caused by a poor installation. Inadequate thickness of foam will cause heat to enter or exit through poorly insulated areas. Contraction of the foam from wood studs as well as poor coverage will create air leaks reducing the effectiveness of the insulation. Additionally improper mixing of the spray foam materials and application can result in toxic off-gassing from the polyurethane foam for extended periods of time. Both open and closed cell foams have a high saturation resistance to heat. Open cell foam has a lower water and moisture saturation resistance than closed cell foams.

POLYISOCYANURATE (ISO) PANEL INSULATION

Polyisocyanurate ISO are a liquid foam that is sprayed against a substrate to form a rigid panel. This substrate creates a faced ISO panel. Different substrate or facings also affect the performance of the panel in terms of both durability and permeability. ISO panels are expensive but have R-values as high as R-6.5 per inch. When new their R-values are near R-8 and decrease slightly over time. Foil-faced ISO panels are considered impermeable and are used as an exterior vapor barrier and insulation. More permeable ISO panels are faced with fiberglass and can be used without creating a vapor barrier.

Disadvantages to ISO panels include their high cost, vulnerability to air leaking around seams and is difficult installation around obstacles or odd shaped spaces. Another significant disadvantage of this type of insulation is its relative high water absorption. This transfer of water into the materials significantly reduces its insulation ability and can also serve as a habitat for mold growth. Typically these panels have a high saturation resistance to heat as long as they are compromised with moisture or water absorption.

EXTRUDED POLYSTYRENE (XPS) INSULATION

Extruded polystyrene (XPS) rigid foam is colored blue or pink with a smooth plastic surface. XPS panels typically aren't faced with other material, but can be used with a house wrap or other insulation. The R-value of XPS is moderately high, about 5 R's per inch. In laboratory testing, XPS foam doesn't absorb water to the degree that other materials do, but even slight moisture absorption drastically reduces its R-value. Real world testing in both roofing and below grade applications indicate that XPS retains significant moisture and presents dramatically reduced R-values.

XPS panels appear denser and feel stronger than other types of insulation making it a versatile rigid foam. XPS panels are still vulnerable to air leaks around seams and are difficult to install around obstacles or odd shaped spaces. Additionally the off-gassing of XPS can contain toxic blowing agents and chemicals used in the production of the foam. The cost of XPS is between polyisocyanurate ISO and expanded polystyrene. XPS does have a higher heat saturation resistance as long as it is not compromised with moisture or water absorption.

EXPANDED POLYSTYRENE (EPS) INSULATION

Expanded Polystyrene (EPS) insulation is a dimensionally stable, rigid foam insulation that can be applied in sheets to the exterior of a home or business, reducing air leaks, and vapor penetration. EPS can be installed below grade, above grade, on floors and roofs. It can serve as a highly effective sound dampener. In EPS foam the cells (beads) are expanded using steam, are sealed, and do not absorb moisture, and continue to serve as a dead air space. This empowers EPS to maintain its insulative value, even in a saturated condition. Moisture is only absorbed between the expanded beads, and there is very little space to hold water, and these spaces are discontinuous throughout the foam. This also allows moisture to escape again.

One great advantage of EPS insulation is that it becomes more efficient and effective as the temperature drops. Like all other insulation materials waterproofing and proper drainage is required in below grade applications. EPS has both a high moisture and heat saturation resistance thus giving it some of the greatest benefits when used as an insulator for structures.

EXPANDED POLYSTYRENE (EPS) FOAM MANUFACTURING

Expanded polystyrene (EPS) is a rigid and tough, closed-cell foam. It is the exact same material mentioned as mentioned above. It is usually white and made of pre-expanded polystyrene beads. EPS foam is the lowest cost foam on the market today. It is expanded using steam and contains no harmful gasses that will leak into the environment. It is a stable foam that does not expand or shrink after the initial manufacturing process. It does not compress over time and when properly protected from UV light does not degrade. This makes it very a effective insulation in both above and below grade applications. In addition to EPS's other benefits EPS has a very high saturation resistance for both moisture and heat. This allows the material to maintain its insulation value when other insulation types have long lost their effectiveness. This lowers energy bills for the structure's owners and keeps occupants more comfortable for the life of the structure.

EPS FOAM IN INSULATING CONCRETE FORMS CONSTRUCTION

ICF construction takes the advantages of expanded polystyrene (EPS) and adds the additional benefits of structurally reinforced concrete. ICFs consist of 2 layers of EPS foam, 1 interior and 1 exterior, in varying thicknesses, with a poured concrete core. This can yield a performance R-value of R-30 to upwards of R-60 depending on the amount of insulation, climate, solar placement, and other factors.

The seamless poured in place nature of ICFs creates a solid wall which eliminates any air movement or leaks through the wall. Extremely tight seals around penetrations and openings, prevent air leaks and drafts, which create cold spots in the winter, and hot spots in the summer.

The concrete core is bonded to the footing and also acts as a heat sink drawing excess heat away from the wall core and into the soil below. Alternatively, it also helps to conduct the latent heat in the soil when the temperatures drop, minimizing the temperature drop at the core, and helping to maintain a more constant temperature inside. This natural convection balances toward a stable wall temperature and requiring less energy to maintain a consistent temperature in the home.

THERMAL MASS

The dense mass concrete serves to store energy for longer periods of time and resists changes to its temperature. Large thermal mass walls when insulated reduce the temperature swings inside by delaying the cooling or warming that is transferred indoors. The high conductivity of concrete and being thermally coupled to the soil creates a large reservoir for excess heat to be absorbed, preventing its transfer indoors.

Comparing thermal images of ICF homes to cavity wall homes demonstrate a clear difference. Even in well insulated wood frame construction homes, the studs in the wall are visible and the entire wall glows red or orange showing the wall temperature. ICF walls only shows heat around the openings. Continuous insulation, the solid concrete core and the lack of thermal bridges creates a very consistent infrared image, and clearly shows the superior insulation available with ICF walls.

FIRE PROTECTION

Additional benefits of ICF construction outside of its insulative ability include its function as a fire wall, with 3 – 4 hours of protection. This is additional time for your family to get to safety and protection for the valuable belongings inside your home. Concrete doesn't burn, and the fuel contained in the EPS is very minimal and it requires more than 680°F (360°C) to ignite. Failure to maintain that temperature will result in the fire extinguishing itself. Below that temperature the EPS foam will soften slightly and melt. When combined with a fire barrier as recommended by the International Code Council's (ICC) International Residential Code (IRC) and International Building Code (IBC) and Canadian Construction Materials Centre (CCMC), such as sheetrock or brick on the outside of the ICF walls resists fire more than any other type of material.

This total reduction in flammable materials within the exterior walls helps to minimize the damage from fire. In many cases, the ICF walls can simply be re-insulated and used for the rebuild.

DISASTER RESISTANCE

ICF walls are inherently impact resistant, and can provide protection against wind and flying debris encountered in hurricanes and even tornados. ICFs have also been shown to resist projectiles, such as handgun and small arms, and even stands up to explosions and better than a plain poured concrete wall. The EPS foam absorbs the impact energy of explosions, flying debris, and projectiles. The integrated nature of the structure, carrying reinforcement from the footings through to the roof structure provides dramatic wind resistance. ICFs are commonly used to create safe rooms and even normal structures that can resist wind speeds exceeding 150 mph. The reinforced concrete wall structure absorbs and distributes the energy throughout the structure allowing it to withstand tremendous forces.

MOLD, MILDEW AND PESTS

The ICF material is not a growth medium or food source for mold or mildew and isn't edible for pests. Proper precautions should be taken in termite prone areas to prevent termites from entering the foam and creating a concealed path to wood in the attic, eaves, or other areas of the home.

The highly alkaline environment of the concrete core serves to limit or prevent mold or mildew growth. The concrete core helps to deter rodents and insects from entering the home around penetrations or directly through the wall by tunneling.

SUMMARY

ICF construction combines the advantages of expanded polystyrene (EPS) foam with the additional benefits of structurally reinforced concrete. ICFs outperform other wall systems and insulation methods through the sheer scale of real benefits in one package. Installation time, ease of use, sound proofing, disaster resistance, fire resistance, insulation value, and safety combined with strength, unparalleled efficiency and durability. Achieving these benefits in a cost effective manner with other methods is not practical. ICFs are a total building package exceeding the needs of today's homes and future-proofing them for tomorrow.

REFERENCES

EPS Industry Association, EPS Below Grade Series 105, March 2014, XPS Insulation Extracted After Field Exposure Confirms High Water Absorption & Diminished R-Value , http://epsindustry.org/sites/default/files/EPS%20Below%20Grade%20105.pdf

EPS Industry Association, EPS Below Grade Series 104, February 2014, Drying Potential of Polystyrene Insulations Under Extreme Environmental Cycling Conditions

Owens Corning, Comparing Rigid Foam Plastic Insulations, http://insulation.owenscorning.com/WorkArea/DownloadAsset.aspx?id=898

Rigid Insulation Board: R-value Packed into a Rigid Foam Panel, http://www.drenergysaver.com/insulation/insulation-materials/rigid-insulation-board.html

CBCNews, Spray foam insulation can make some homes unlivable, October 25, 2013, http://www.cbc.ca/news/spray-foam-insulation-can-make-some-homes-unlivable-1.2224287

Energy Vanguard Blog, 4 Pitfalls of Spray Foam Insulation, June 29, 2010, http://www.energyvanguard.com/blog-building-science-HERS-BPI/bid/25546/4-Pitfalls-of-Spray-Foam-Insulation

How It's Made – Stone Wool Insulation, Discovery Channel, Panos Egglezos, https://www.youtube.com/watch?v=t6FWPTZjwLo

Differences between Glass 7 Rock Wool, Ehow, http://www.ehow.com/info_12186172_difference-between-glass-rock-wool.html

This document was originally published by BuildBlock Building Systems in 2015.