Types of Insulation

Insulation consists of a variety of materials and comes in many forms. These include fibrous insulation, foam insulation, insulated panels, straw panels, and insulating masonry products, as well as specialized devices to aid proper insulation techniques. Alternatives to conventional fiberglass, cellulose, and mineral wool are constantly being explored and introduced to the market place. These new types of insulation serve different needs. The following describes the new insulation types without manufacturer or product name unless it is needed to convey an adequate description. In order to convert English (Imperial) unit R-values into metric (International System units, or SI) equivalents, you can use the conversion factors listed before the bibliography.

Fibrous Insulations

Fiberglass Insulation

Manufacturers now produce medium and high density fiberglass batt insulation with higher R-values (ft2h°F/Btu) than existing low density batts. These new products are appropriate for insulating building envelopes with limited cavity space (for example, cathedral ceilings). Medium density batts have twice the fiberglass as the low density batts, and the high density batts have three times as much. Because they contain more fiberglass, these higher density batts are more expensive than low density batts.

High density fiberglass batts for insulating 2 ´ 4 inch (38 ´ 89 millimeter [mm]) stud-framed wall construction are rated at R-15, compared to R-11 for standard batts and R-13 for medium density batts. A medium density batt for 2 ´ 6 inch (38 ´ 140 mm) frame wall construction is rated at R-21. For cathedral ceilings, high density batts rated at R-30 for 8 1/2 inch (216 mm) spaces, and R-38 for 10 inch (254 mm) spaces are available.

One manufacturer markets an unconventional fibrous insulation product. It is a combination of two types of glass strands laminated together. This new form has several advantages over conventional fiberglass. The natural, random curl of the material greatly reduces skin irritation, produces high loft, and requires no chemical binder. The combined glass strands are larger than the fibers implicated in respiratory diseases.

At approximately R-3 per inch, it compares well to a conventional fiberglass batt. It is currently available only in a perforated plastic batt configuration. Similar insulations, without the plastic wrapping, "accordion," or stretch out, when you attempt to lift them.

Cotton Insulation

Cotton thermal insulation is available as batt or loose fill. It consists of recycled cotton, polyester, and nylon fibers, and is treated with a flame retardant and insect/rodent repellents. It meets the same Class I standards for fire resistance as fiberglass insulation. The batts come in standard widths, thickness', and R-values with a Kraft paper facing on one side. Unlike conventional fiberglass insulation, cotton insulation does not irritate the skin when being installed. Cotton insulation is not yet readily available in all sections of the country. Check with your local building supply store or the manufacturer for ordering information (see the manufacturer contact list below).

Mineral Wool Insulation

Mineral wool refers to three types of insulation made from raw materials spun into loose fill or batt products:

- "glass wool," or "fiberglass," made from recycled glass or silicates;
- "rock wool," made from virgin basalt, an igneous rock; and
- "slag wool," made from steel-mill slag.
- Most of the "mineral wool" made in the United States is actually "slag wool". Most U.S.-made mineral wool is stiff and brittle. Mineral wool insulation is fire resistant and aids sound-proofing.

A softer, mineral wool batt product is now available. The edge of this new Canadian-made batt is highly compressible. This allows insertion of the batt between framing members. It then expands to continuously press against both framing members. The result is a friction-fit installation that increases the overall insulation effectiveness. This batting is more dense than fiberglass, so it should be less subject to air convection thermal losses. Its thermal resistance is approximately R-3.7 per inch.

Until recently, the friction fit batt was only available outside the United States. The cost of soft mineral wool batt insulation is about 15% higher than fiberglass, and it is still more fragile than fiberglass.

Plastic Fiber Insulation

Another new type of insulation entering the marketplace is plastic fiber insulation. Plastic fiber batts are made from recycled polyethylene terephthalate (PET), commonly used to make milk containers. The fibers are thick, making extremely soft batt insulation that looks like high-density fiberglass. R-values vary with batt density:

- R-3.8 per inch at 1.0 lb./ft3 density
- R-4.3 per inch at 3.0 lb/ft3 density
- The recycled content and clean manufacturing process help make this insulation a good addition to the market. The insulation also does not irritate the skin. It does not burn when exposed to an open flame, but it melts at a low temperature-a definite disadvantage. The batts are also difficult to cut with standard job-site tools, and the insulation tends to accordion when handled. Major U.S. insulation manufacturers are expected to produce plastic fiber insulation products within the next few years.

Other Fibers

Several other fibers are being analyzed for their potential insulating properties. The most notable of these include wool, hemp, and straw. Wool and hemp insulations are commercially available in the United States. Both products offer similar R-values to other fibrous insulations. Straw is a form of cellulose with

reasonably good insulating properties.
Straw bale construction opportunities, once popular with pioneers, are gaining favor with cost-conscious, hands-on homeowners interested in energy efficiency. Depending on the orientation of the straw, bales tested according to ASTM procedures resulted in bale R-values of R-2.4 to R-3.0 per inch. One straw bale expert claims R-2.4 is more representative of in-situ straw bale construction. A typical medium-sized, three-wire bale may be 23 x 16 x 42 inches (610 x 406 x 1067 mm), weigh 75-85 pounds (34-38.5 kilograms (kg)), and yield R-56.5 walls (or R-2.4/inch). The smaller 18 x 14 x 36 inch (457 x 356 x 914 mm) bales, at 50-60 pounds (22.7-27.2 kg), can create R-43.2 (or R-2.4/inch) assemblies. Compressed straw board products are beginning to enter the construction market as well.

Insulating Foams

Urethane Foam

A new closed-cell polyurethane foam insulation uses HFC-134a, a nonchlorine blowing agent, which is not atmospheric ozone-depleting. The new product offers a reported aged R-value of R-6.5 per inch thickness. Because of the new blowing agent, it is roughly three times as expensive as traditional polyurethane insulations. Although it does not affect the ozone layer, a recent study showed that high concentrations of HFC-134a in the environment may damage wetlands and plant growth.
Low density open-cell polyurethane foams-0.5 pounds per cubic foot (lb/ft3) versus 2.0 lb/ft3(8.0-32.0 kilograms per cubic meter (kg/m3)) for conventional urethane-are similar to conventional polyurethane foam. These "half-pound urethanes" are semi-flexible, cellular plastics. While most polyurethane insulations use ozone-depleting fluorocarbon blowing agents, low density varieties use water or carbon dioxide (CO2).
Half-pound urethanes may be sprayed in place where exposed cavities are common, such as in new construction. One manufacturer offers a slightly different formulation, which trained installers pour into cavities. This is unique for an expanding foam, since most foam insulation applications of this sort cause bowed and disconnected interior sheathing. The foam is water vapor permeable, while remaining flexible, water repellent, and resistant to wicking of moisture. Polyicynene provides good air sealing and yields R-3.6 per inch thermal resistance.
Half-pound urethane's current installed cost is approximately $1.05 to $1.30 per square foot ($11.25-14.00 per square meter [m2]) to fill a 2 ´ 4 inch (38 ´ 89 mm) stud cavity, compared to $1.75 per square foot ($18.83 per m2) for conventional polyurethane. As with most plastic foams, protect it from exterior exposure and sheathe the interior with an approved fire barrier. This foam insulation will not sustain a flame upon removal of the flame source.

Nitrogen-based Plastic Foam

One manufacturer, Tailored Chemical Products, Inc., markets a two-component plastic foam insulation system that uses compressed air as the installation medium. It is commonly used for filling commercial and industrial masonry

walls. Although this nitrogen-based (urea formaldehyde) plastic resin takes only a minute to set, complete curing may take several weeks. Unlike polyurethane insulations, this product does not expand as it cures. The product also breathes better than polyurethane, allowing moisture vapor to pass through it.
The manufacturer does not recommended this product for attic or ceiling applications for two reasons: it seeps through small cracks, and the product breaks down at prolonged temperatures above 190°F (88°C). It contains neither petrochemicals nor fire retardant chemicals. This insulation has an R-value of about 4.6 per inch and costs are competitive with loose-fill or poured-in insulations.

Cementitious Insulation

Air-Krete™ is a magnesium silicate, cementitious (cement-based) insulation that is foamed or pumped into closed cavities. Do this before installing the inner wall finish material. Installed consistency of the foam is similar to shaving cream that then cures to something akin to thick pudding. It is easily damaged by water. (See article titled "Air Krete-The Other 'New' Kid on the Block" in Bibliography below.) This insulation is made from material extracted from seawater. Its non-toxic attributes make it very popular with chemically sensitive individuals. Since it is not temperature sensitive, it can be installed indoors under any weather conditions. This insulation is also non-flammable. Air-Krete™ has an R-value of about 3.9 per inch and costs about $1.50 per square foot ($16.15 m2) to fill a 2 ´ 4 inch (38 ´ 89 mm) stud wall cavity.

Phenolic Foam

For several years, a high R-value phenolic rigid insulation board was on the market. Because the foam boards often shrank, warped, or decomposed, manufacturers stopped making it. Foamed-in phenolic insulation is still available. It has a R-4.8 per inch resistance value, uses air instead of an ozone-harming fluorocarbon as a blowing agent, and has good fire resistance. The manufacturer does not restrict installation due to extreme temperatures, providing it is not left permanently exposed. The major disadvantage of phenolic foam is its shrinkage, which ranges from 0.5 to 1.5%.

Foam Insulation Vehicles

At least one company has created a foam "vehicle" that transports one or more insulating materials such as fiberglass into a cavity. This foam later dissipates, leaving the encapsulated insulation uniformly distributed in the cavity. The product's R-value matches the internally applied insulating material.
One brand of insulation uses high quality fibers such as fiberglass, mineral wool, or cellulose. The thermal resistance value generally approaches the upper limit of attainable R-value of these materials. Its binder is a latex formulation, similar to household glue, and may not be suitable for some individuals. This form of insulation is commonly used in manufactured housing outside of the United States.
Another brand employs a latex adhesive binder to homogeneously install standard loose-fill insulation materials. The product uses a proprietary blown-in

technique and is not foamed-in. Refer to the R-values for the three types of insulation:

- Fiberglass: R-4.0 to R-4.3 per inch
- Mineral Wool: R-3.8 per inch
- Cellulose: R-3.7 per inch

Rigid Insulating Panels

Composite Insulating Panels

Composite insulation panels include structural insulating panels (SIP) and insulated roof panels. Structural insulated panels, "insulated sandwich panels," or "stress (ed)-skin panels," consist of an insulated core sheathed on two sides. The insulation is usually a foam-based plastic such as polystyrene or isocyanurate, but foam-straw composites are occasionally available. Sheathing materials include plywood, oriented strand board (OSB), and waferboard; interior sheathing materials also include drywall. The panels range in size, but are most common in 4 ´ 8 and 4 ´ 9 foot (1.2 ´ 2.4 and 1.2 ´ 2.7 meter) varieties. Because of its integral strength, composite panel systems reduce the need for structural lumber, opportunities for air leaks, and job site assembly time. A comparison of stick-built and panel-built test houses shows a slight energy saving with structural panel construction. Because these panels also reduce sound transmission, some professionals use them for interior partitions.
Insulated roof panels have a nailable sheathing layer over an insulation base, typically rigid foam. Use this product only where you need sheathing on one side, for example; a retrofit application over an existing sheathed roof. These panels are very effective at increasing the R-value of a roof. Scandinavians have used this type of application for years to help prevent condensation inside attics. The insulated roof panels are also available with air channels just under the exterior sheathing for ventilated roof designs.

Straw Panels

Compressed-straw panels have been used in hundreds of thousands of buildings worldwide. The process of fusing straw into boards under pressure requires no adhesive. It was developed in the 1930s. Panels are usually 2 to 4 inches (51-102 mm) thick and faced with heavy-weight Kraft paper on each side. Although manufacturer claims vary, R-values realistically range from about R-1.4 to R-2 per inch. These sound-absorbing panels also make effective interior partitions. Some manufacturers have developed structural insulated panels from multiple-layered, compressed-straw panels.

Insulating Masonry Products

Manufacturers have also developed a variety of innovative permanent insulated concrete form systems. These systems include internally braced, rigid foam board formwork and stackable hollow-core foam blocks. The rigid board formwork consists of exterior panels of rigid polystyrene or polyurethane separated by structural plastic ties. Adding appropriate reinforcing and poured concrete follows. Since the insulated formwork remains in place, the result is an insulated concrete wall assembly.

Because of its flammability, building codes do not permit exposed interior foam insulation in habitable spaces. With insulated concrete form systems, you must sheathe the interior foam surface with an appropriate fire-resistant material. Most codes accept fire-resistant drywall as an acceptable fire retarder. Also, do not overlook the need to protect the exterior insulation from damaging solar radiation (ultraviolet light degrades the plastics) and physical impact (dents, scratches, and abrasions).

Other systems use the rigid insulation board in the center of the concrete wall. These systems are particularly applicable to insulated tilt-wall construction, where walls are poured within bordering forms laid on a concrete slab, then raised, or "tilted," into position. Because the insulation board is inside the wall, it reduces potential problems relating to building security, fire, and insect infestation.

Stackable, permanent insulation block systems typically involve use of hollow core, rigid polystyrene or polyurethane blocks that interlock to create the formwork for the walls. Concrete around steel reinforcing inside block cavities structurally stabilizes the wall assembly. While one manufacturer's concrete-coated, expanded polystyrene 12 inch (305 mm) thick block wall with concrete infill yields a very fire-resistant R-24 assembly, this is unique to the stackable insulation block systems.

Insulation blocks and formwork connecting inner and outer insulation faces with bonding struts of rigid foam provide insects direct access through this wall element. Since many insects burrow within these insulations, a better solution may be to pick a system that uses an insect resistant material.

Today, lightweight, insulated concrete blocks take on many different shapes and compositions. The better concrete masonry units reduce the area of connecting webs as much as possible. The cores are filled insulation-poured-in, blown-in, or foamed-in-except for those cells that require structural steel reinforcing and concrete infill. This raises the average wall R-value.

Some block makers coat polystyrene beads with a thin film of concrete. The concrete serves to bond the polystyrene while providing limited structural integrity. Expanded polystyrene mixed with Portland cement, sand, and chemical additives are the most common group of ingredients. These make surface bonded wall assemblies with a wall R-value of R-1 per inch thickness. Polystyrene inserts placed in the block cores increase the unit thermal resistance to about R-2 per inch.

Hollow-core masonry units made with a mix of concrete and wood chips are also available. You install them by stacking the units without using mortar (dry-stacking). Structural stability comes from the concrete fill and appropriate reinforcing required throughout for structural walls. The wood component is subject to the effects of moisture and insects, however.

Two varieties of solid, precast autoclaved concrete masonry units are now available in the United States: autoclaved aerated concrete (AAC), and autoclaved cellular concrete (ACC). This class of material has been commonly used in European construction since the late 1940s. Air makes up 80% (by volume) of the material. It has ten times the insulating value of conventional concrete. The R-1.1 per inch blocks are large, light, and flat with a consistency much like a hard, fine sponge. When laid with a thin mortar layer, plaster and stucco provide simple, attractive finish treatments. Autoclaved concrete is easily sawn, nailed, and shaped with ordinary tools. Since the material absorbs water readily, it requires protection from moisture.

Precast autoclaved cellular concrete uses fly ash instead of high-silica sand as its distinguishing component. Fly ash is a waste ash produced from burning coal in electric power plants. The fly ash is the material that differentiates ACC from AAC.

Specialized Devices

A wide variety of rigid insulation inserts are available to fill many critical locations in the insulated envelope of houses. Some examples are to use inserts as air chutes, insulation dams, concrete block fillers, and ice dam retarders. Expanding foams efficiently seal and weatherize homes. Devices as simple as cardboard can be used to provide an insulation dam to help keep loose-fill insulating material around attic ductwork.

Conclusion

Many types of alternative insulation are rapidly becoming incorporated into conventional construction. They may provide a more convenient and often healthier approach to increasing the energy efficiency of a building. It is important to note, however, that because these new materials have been on the market for a short time, they may not be widely available. Therefore, performance for some of these materials may be poorly documented. Always research a material's characteristics and suitability to a particular situation before buying any of these new products.

Conversion FACTORS

R-Value Conversions	To Get	Multiply	By
Thermal Resistance (R)	RSI (m2 C/W)	R(ft2h F/Btu)	0.1761
Insulation R/unit Thickness	RSI/mm	R/in.	0.00693