Figure 4.1 Primary Structural Components for a Typical 20' ISO Shipping Container.

Note: On some ISO shelters, some of the primary structural components may be concealed within the wall, roof, and floor panels. The areas where the adjacent panels join will be thoroughly inspected. This inspection will meet the criteria for the Wall Beams and the Roof Beams.

- **4.1.1 Corner Fitting.** Internationally standard fitting (casting) located at the eight corners of the container structure to provide means of handling, stacking and securing containers. Specifications are defined in ISO 1161.

- **4.1.2 Corner Post.** Vertical structural member located at the four corners of the container and to which the corner fittings are joined.

- **4.1.3 Door Header.** Lateral structural member situated over the door opening and joined to the corner fittings in the door end frame.

- **4.1.4 Door Sill.** Lateral structural member at the bottom of the door opening and joined to the corner fittings in the door end frame.
• **4.1.5 Rear End Frame.** The structural assembly at the rear (door end) of the container consisting of the door sill and header joined at the rear corner fittings to the rear corner posts to form the door opening.

• **4.1.6 Top End Rail.** Lateral structural member situated at the top edge of the front end (opposite the door end) of the container and joined to the corner fittings.

• **4.1.7 Bottom End Rail.** Lateral structural member situated at the bottom edge of the front end (opposite the door end) of the container and joined to the corner fittings.

• **4.1.8 Front End Frame.** The structural assembly at the front end (opposite the door end) of the container consisting of top and bottom end rails joined at the front corner fittings to the front corner posts.

• **4.1.9 Top Side Rail.** Longitudinal structural member situated at the top edge of each side of the container and joined to the corner fittings of the end frames.

• **4.1.10 Bottom Side Rail.** Longitudinal structural member situated at the bottom edge of each side of the container and joined to the corner fittings to form a part of the understructure.

• **4.1.11 Cross Member.** Lateral structural member attached to the bottom side rails that supports the flooring.

• **4.1.12 Understructure.** An assembly consisting of bottom side and end rails, door sill (when applicable), cross members and forklift pockets.

• **4.1.13 Forklift Pocket.** Reinforced tunnel (installed in pairs) situated transversely across the understructure and providing openings in the bottom side rails at ISO prescribed positions to enable either empty capacity or empty and loaded capacity container handling by forklift equipment.

• **4.1.14 Forklift Pocket Strap.** The plate welded to the bottom of each forklift pocket opening or part of bottom siderail. The forklift pocket strap is a component of the forklift pocket.

• **4.1.15 Gooseneck Tunnel.** Recessed area in the forward portion of the understructure to accommodate transport by a gooseneck chassis. This feature is more common in forty foot and longer containers.

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**Figure 4.2 Exploded axonometric view of a Typical 20' ISO Shipping Container.**
• **4.2 Walls, Roof, and Floor.** Refer to Figure 4.2A

• **4.2.1 Fiberglass Reinforced Plywood (FRP).** A material constructed of laminates of fiberglass, polyester resins, and plywood, also known as sandwich panel.

• **4.2.2 Wall Panel.** Corrugated or flat sheet steel, a riveted or bonded aluminum sheet and wall post assembly, FRP, foam and beam, aluminum, or honeycomb material that forms the side wall or end wall.

• **4.2.3 Wall Post.** Interior or exterior intermediate vertical component to which sheet aluminum or steel is riveted or welded to form a wall panel.

• **4.2.4 Wall Beam.** Encapsulated vertical component to which sheet aluminum or steel is bonded to form a wall panel. This is found in foam and beam panels.

• **4.2.5 Marking Panel.** A side wall panel of a corrugated steel configured with a flat portion used for the display of markings and placards. (4.2A)

• **4.2.6 Lining.** Plywood or other like material attached to the interior side and end wall to protect the walls and/or cargo and facilitate loading operations.

• **4.2.7 Lining Shield.** A strip of thin metal installed at the bottom of the interior walls to protect the lower portion of the lining from damage by materials handling equipment during loading or unloading operations.

• **4.2.8 Kick Plate.** A common name for a lining shield installed on the lower portion of the interior front end wall.

• **4.2.9 Ventilator.** Two or more devices permanently attached to the side or end wall panel that provides openings for the exchange of air (but not water) between the outside and the container interior. (4.2A)

• **4.2.10 Roof Panel.** Corrugated or flat sheet steel, sheet aluminum, FRP, or foam and beam and aluminum honeycomb panel that forms the top closure of the container. (4.2A)

• **4.2.11 Roof Bow.** Lateral non-structural member attached to the top side rails and supporting the underside of the roof panel. Roof bows used with removable cover (tarp) assembly are unattached. Not all container designs require roof bows.
• **4.2.12 Roof Beam.** Encapsulated horizontal component to which sheet aluminum or steel is bonded to form a roof panel.

• **4.2.13 Roof Reinforcement Plate.** An additional metal plate on the interior or exterior of the roof panel adjacent to the top corner fittings that provides protection of the roof panel or top rail components from misaligned handling equipment.

• **4.2.14 Tarp.** Jargon for “tarpaulin” which is a waterproof and flexible fabric used for covering the top of an open-top container. This covering is referred to as a “Tilt” in some countries.

• **4.2.15 TIR Cable.** Plastic sheathed wire rope that is designed in accordance with TIR customs convention (Refer to paragraph 4.5.6) and is threaded through the welded loops on the sides, end panels and door panels of an open-top container to secure the tarp.

• **4.2.16 Flooring.** Material that is supported by the cross members and bottom rails to form a load bearing surface for the cargo. The flooring is usually constructed of laminated wood planks, plywood sheets, or other composition material and is screwed or bolted to the cross members. Some containers have welded steel or aluminum flooring, sandwich panels or a combination of metal and wood. (4.2A)

• **4.2.17 Joint Strip.** A formed steel or aluminum strip (usually hat-shaped section) installed between joints of the plywood sheet flooring or joints of the plywood sheet lining to help integrate and support the edges of the plywood. (4.2A)

• **4.2.18 Threshold plate.** Plate forward of the door sill to protect the entrance area of the container floor. This plate is commonly referred to as a crash plate.

• **4.2.19 Steps.** Folding steps are found on some ISO Shelters and are used to gain access to the roof. They must be folded up prior to transporting shelter.

• **4.2.20 Sandwich Panel.** A type of fixed or removable panel construction used in ISO Shelters consisting of a thin inner and outer sheet aluminum skin, bonded or fastened to a core constructed of either honeycomb or structural foam and aluminum beams.

• **4.2.21 Striker Plate.** An additional metal plate on the exterior of the roof panel adjacent to the top corner fittings that provides protection of the roof panel or top rail components from misaligned handling equipment.

• **4.2.22 Sling Pad.** An additional metal plate on the exterior of the roof panel located in the center of the roof panel that provides protection to the panel from lowered handling equipment.

ISO Shipping Containers and Building Code Requirements

**General Comments on ISO Shipping Container’s Inherent Capacity to Satisfy Building Code Requirements in Shipping Container House Applications:**

ISO shipping cargo containers are tested in accordance with the requirements of International Standard ISO 1496/1 which stipulates static and dynamic design load factors to be complied with. In the case of a 20’ steel container, it is designed to have a maximum gross weight of 52,910 lbs (typically has a tare weight of around 5,000 lbs and a payload (P) potential of 47,910 lbs). The container when loaded to its maximum gross weight must be capable of withstanding imposed loads of 2g downwards, 0.6g lateral and 2g longitudinal plus be able to withstand eight similar containers loaded to maximum gross weight stacked on top of it in a ships hold or at a land terminal. It therefore has a very sever operational life and, notwithstanding its low tare weight it is very strongly built.

The side walls and end walls/doors have to withstand loadings of 0.6P and 0.4P respectively, these values equate to 28,746 lbs and 19,164 lbs based upon the payload given above. The side wall area in contact with the load is 146.56 sq. ft. giving a pressure of 196 lbs/sq. ft. Corresponding figures for the end wall/doors are 51.78 sq. ft. and 370 lbs/sq. ft. These figures are well in excess of the 20 lbs/sq. ft. wind load required for structures less than 50 ft. high. A wind of 100 MPH produces a pressure of only 30 lbs/sq. ft.

The roof load test is 660 lbs over an area of 2’ x 1’ applied to the weakest part of the roof. The load is usually applied at the center of the containers positioned with the 2’ dimension aligned longitudinally. Thus the roof
is able to support an imposed load of a minimum of 330 lbs/sq. ft. The design is easily capable of supporting the basic snow loads of 30 lbs per sq. ft. evenly distributed.

It is difficult to quantify uplift and suction forces. Unlike a building, the roof of a container is an integral part of the structure; it is continuously welded around its entire periphery and is itself made from sheets of corrugated 14 ga. Cor-Ten steel also continuously welded together. This steel, also used for the side and end walls has a minimum yield strength of 50 ksi, and tensile of 70 ksi. The probability of the roof being removed by these forces is practically zero as the entire container structure would have to be destroyed for this to happen.

However, it is not unusual for the complete container to be lifted or blown over if it is not secured to the ground in storm or hurricane conditions. This would be prevented by adequate foundation design which is the responsibility of the customer. As you know when containers do blow over in container yards the resulting damage is almost always minimal, another testimonial to their strength.

The floor is design to pass a concentrated load test of 16,000 lbs over a foot print of 44 sq. inches. The floor has also been designed to pass a test at twice its rated payload capacity of 47,895 for a 20 container and 58,823 lbs for a 40' container when evenly distributed.

The boxes are suitable for earthquake areas of seismic rating of up to the California standards.

INFORMATION ABOUT COR-TEN, THE WEATHERING STEEL SHIPPING CONTAINERS ARE MADE FROM.

COR-TEN STEEL USAGE AND RUSTING PROCESS

In the 1930s, the United States Steel Corporation developed Cor-Ten, primarily for use in railway coal wagons. The controlled corrosion that is a feature of the material was a welcome by-product of the need for a tough steel capable of withstanding the rigours of America’s burgeoning marshalling yards and collieries. Because of its inherent toughness, weathering steel (the generic name for Cor-Ten, along with weather-resisting steel) is used extensively for ISO shipping containers.

The civil engineering applications that appeared in the early 1960s made direct use of the improved resistance to corrosion, and it would not be long before the applications in architecture would become apparent. Cor-Ten gets its properties from a careful manipulation of the alloying elements added to steels during the production process. All steel produced by the primary route (in other words, from iron ore as opposed to scrap) comes into being when the iron smelted in blast furnaces is reduced in a converter. The carbon content is lowered and the resultant iron, now steel, is less brittle and has a higher capacity for loading than before. Other material is commonly added during the process. Weathering steel has a combination of chromium, copper, silicon and phosphorus, the amounts depending on the exact attributes required.

Weather-resistant steel works by controlling the rate at which oxygen in the atmosphere can react with the surface of the metal. Iron and steel both rust in the presence of air and water, resulting in the product of corrosion - rust, iron oxide. Non-weather-resisting steels have a relatively porous oxide layer, which can hold moisture and promote further corrosion. After a certain time (dependent on conditions), this rust layer will delaminate from the surface of the metal, exposing the surface and causing more damage. Rusting rates seen on a graph would appear as a series of curves approximating to a straight line.

Cor-Ten exhibits superior corrosion resistance over regular carbon steel as a result of the development of a protective oxide film on the metals surface that slows down further corrosion. Their yield strength allows cost reduction through the ability to design lighter sections into structures. These steels were designed, primarily to be used in unpainted applications where a reduction in maintenance costs, such as painting, were desired. Weathering steels are now being used in a variety of applications, including bridges, rail cars, transmission towers, chimneys and shipbuilding. It is also becoming increasingly popular with sculptors and as an architectural feature.

Cor-Ten is the primary brand name for corrosion resistant products that were developed by United States Steel Corp. Cor-Ten has subsequently been licensed to be produced by other steel producers. There are basically two types of Cor-Ten that are most prevalent, Cor-Ten A (generally up to 12mm thick) and Cor-Ten B (generally 15mm thick and above).

The comparison of Cor-Ten to the ASTM grades is loosely stated as Cor-Ten A is equivalent to ASTM A242 and Cor-Ten B is equivalent to ASTM A588 Grade A. Cor-Ten A and B both meet and/or exceed the requirements of ASTM A606 Type 4.
Considerations for use of Cor-Ten and weathering steels:

1. The actual corrosion loss varies with the environment. For long-life, corrosion allowance must be considered.
2. Crevices and water/dirt traps should be avoided
3. Rust stains may run to adjacent surfaces and cause staining
4. Fasteners should be made of weathering steel
5. Specific low alloy welding rods should be used
6. For an even weathering result, surface blasting may be necessary
7. Weathering steels are unsuitable for use in marine and aggressive industrial environments

Rate of corrosion

The oxide layer on weathering steel is not as porous because it adheres more firmly to the base metal. The curve of rate of corrosion initially progresses at the same rate as ordinary steel, but soon begins to level out. The weathering process is dependent on the aggressiveness of the environment into which the steel is placed. As might be expected, rural sites fare the best and marine ones the worst when it comes to the eventual longevity of the material. Another factor to consider is the aspect of the weathering steel. West- and south-facing surfaces weather at a more even rate and form a more even oxide layer. North- and east-facing surfaces tend to be wetter for longer periods of time and often have areas that are darker and more uneven in colouration. This is unavoidable, unfortunately, and is a feature of the material. In the same way that timber bleaching in red-cedar cladding is regarded as something mildly unpredictable, we should look upon the eventual appearance of the oxide layer in weather-resistant steel as an equally natural, and therefore serendipitous, process.

The wetting and drying cycle is important. Continuous dryness is obviously not a problem, (hence those burned-out Second World War vehicles that litter North Africa and are destined to remain for some time because they don't rust). Continuous wetness can be problematic, however. Some time ago a series of bridges was constructed from weather-resistant steel for some forest roads. The condition of the forest floor was typical, moist and mildly acidic. The bridges rusted in the same way as ordinary steel, with the oxide layer attacked by the corrosion products of leaves and the continual exposure to moisture.

Ideally, to weather in the expected fashion, weather-resistant steel needs wetting and drying cycles. This is because moisture activates the corrosion process but, with the drying, the oxide layer obtains its nonporous state. The more rapid the wet-dry cycle, the more even the oxide layer.

Another factor that can affect the finished appearance is size. One reason the Angel of the North exhibits an even orange layer of rust is because of its mass. The south- and west-facing aspects, which collect the majority of the sun's energy, absorb and transmit sufficient heat to limit the amount of condensation that can form on the rest of the statue. If the north and east aspects are borrowing the heat, they will tend to weather at more or less the same rate.

Cor-Ten A and Cor-Ten B differ primarily in the amounts of phosphorous alloyed into the mixture. Uses reflect the different properties imparted to the steel. The first type is typically produced as sheet or coil (from 1.0mm up to 12mm) and has applications in cladding and ductwork. The second type is more commonly produced as plate (15mm up to 50mm).

Applications of weather-resisting steel vary widely but recently there has been a trend towards an appreciation of the finish in more elegant surroundings. The Royal Court Theatre is a good example of the gentrification process slowly happening to what has been regarded as one of the more muscular industrial products.

Another application is in high-temperature environments. Normal steel grades - that is, carbon or carbon, manganese steels - form an oxide layer in the absence of moisture at around -100C. Weather-resisting grades of steel typically exhibit an improvement in the region 50C. In practice, this means that where surface loss due to oxidation in normal steels might be 1 mm per year, the temperature to achieve the same loss in weather-
resisting grades would be that much higher. Load bearing capacity can be maintained up to temperatures of about 450°C. Improved abrasion resistance (as in the coal wagons) is another feature.

**Welding**

If its less than 10mm thick and the weld is a single pass (a fillet) you can weld it with mild steel. If its MIG ER70s-6 / SG2 / G3Si1. You will get enough dilution from the plate to weatherise the weld.

If its over 10mm or if its multi-pass you need either a similar composition (nominally 1%Ni 0.5%Cu) usually classified as ER80S-G or ER80S-W alternatively you can use a 2.5% Nickel steel ER80S-Ni2

Corten "A" is a weathering steel that has a higher than normal copper content, this forms a rust preventative oxide on the surface that prevents "weathering" you can get a specific wire for corten but the general consensus is to treat it like s355 type material.

**Wetting-drying cycle**

Designing in weathering steel is primarily concerned with ensuring the wetting-drying cycle, which forms the protective oxide layer, is allowed to happen. As in previous technical articles, the importance of detailing out pockets, crevices, upward-facing channels and so on cannot be over-emphasised. Where such a condition is unavoidable, say for structural reasons, then it is important to include drainage holes or to ensure sufficient ventilation. Anything that retains moisture should be discouraged, again preferably by design.

Leaves, moss and the proximity of trees can all affect the performance of the material adversely.

When viewed in conjunction with the intended environment, detailing can make the difference between success and failure of a weather-resisting steel structure. There are some environments where special care must be exercised.

1. First, atmospheres where there is a high concentration of industrial fumes.
2. Second, submerging, or burying in the ground. If this is unavoidable other methods of protection can be employed such as concrete encasement or cathodic protection.
3. Third, exposure to chloride ions, such as in a marine environment or close to a highway, where exposure to salt may pose a problem. Salt can affect the oxide layer because it is hygroscopic and will retain moisture.

Another detailing problem is that of runoff from the steel. It will be impossible, especially while the oxide layer is forming, to prevent the run off from staining susceptible materials unless the detailing of channels and the position of such materials is considered carefully.

**Organic coatings**

Non-porous materials are much better. Glass, stainless steel, glazed bricks and tiles, washable organic coatings and paints, aluminium (anodised or non-anodised), polycarbonates and neoprene remain unaffected or can be cleaned if necessary.

The rules that apply regarding the electrochemical series of metals should be observed. If dissimilar metals are to be placed in proximity to weathering steel, then good detailing practice should ensure the elimination of traps for water and / or the separation of the metal, with an inert material.

This will apply in some cases with fixing techniques. It is common to specify weathering steel nuts and bolts in conjunction with the main structure. It is also possible to use stainless steel or even galvanised steel fixings, providing the latter are isolated from the surface of the weathering steel. Welding poses no problem. Most manufacturers of welding materials provide consumables suitable for the fabrication of weather-resisting steel (see page 4).

**Restrictions**
The hygroscopic nature of salt adversely affects the 'patina' as it maintains a continuously damp environment on the metal surface. Consequently, as a general rule, unprotected weathering steel should not be used within 2km of the coastline.

The texture of weathering steel is influenced by the orientation of the structure and the degree of shelter it provides. Surfaces facing south and west, and those subject to frequent wet and dry cycles, develop a smoother fine-grained texture. Sheltered structures, and surfaces facing north and east (slower drying), tend to develop a coarse granular texture.

Concrete, stone and unglazed brick may suffer from oxide staining when in contact with weathering steel. Connections to dissimilar materials, such as zinc or cadmium plated bolts, should be avoided.

It is possible to paint weather-resistant steel. The requirements of such a paint system do not differ from those required for normal grades of steel. One significant advantage that occurs when doing this (as is common in containerised storage) is that damage to the paint does not result in under-creep corrosion to the surrounding painted area.

Weathering steels are high strength, low alloy, weldable structural steels that possess good weather resistance in many atmospheric conditions without the need for protective coatings. They contain up to 2.5% alloying elements, e.g. chromium, copper and nickel. On exposure to air, a protective rust patina forms that adheres to the surface of the steel. This layer causes the rate of corrosion to slow so that after 2-5 years, corrosion almost ceases. Requirement for the formation of the protective corrosion product layer is regular wetting and curing of the surface. Long wet periods may prevent the formation of the protective layer.

Wet environments, immersed or buried conditions are unsuitable for weathering steels.

INSULATION

BUILDING ENVELOPE – INSULATION

It would be hard to find a more critical decision than your choice of insulation. In addition to R-value, you also need to look at these materials' relationship with the rest of the building envelope. Though the fundamentals of building heating and cooling are unchanging, new products and evolving best practices allow insulation to play an increasingly important role in whole-house system design.

A comprehensive insulation strategy takes into consideration the products’ efficiency, cost, application techniques, and environmental impact. One also needs to factor in comfort and durability. Some of the products and practices being used to insulate today’s high-performance homes are outlined below.

Thermal Resistance Defined

Thermal energy travels from hot to cold, so we lose heat from inside to outside in cold months and lose our cool in the summer as heat tries to move indoors.

Insulation’s job is to slow down that transfer of heat. R-value is a measurement of a material’s ability to resist the transfer of energy; as we all know, the higher the R-value, the more effective the insulation (a chart of typical R-values is available in the R-Value Table section link here). By doubling the thickness of an insulating material, we can double its R-value, cutting energy transfer in half; however, the law of diminishing returns means that the same resources applied over again yield half the net change. Looking at a complete wall assembly design and its energy analysis is the only way to find the right balance between construction cost, long-term energy savings, and overall environmental impact.
Product Selection
Below is a brief review of the major types of insulation, from simplest to more complex and from least cost to most. Remember: As we improve our thermal enclosure, we also can reduce the complexity and size of our heating and cooling systems. This reduces first cost and saves on long-term operating cost. In a Life Cycle Assessment of this approach, higher-performing insulation will result in the best choice.

BATTs: If you are considering using batt insulation, select high-density batts with a higher insulating value. Remember that careful installation is vital; too often, poor installation techniques, design complexities, framing challenges, and other factors can cause gaps and voids between and around batts, seriously deteriorating their performance over time.

LOOSE-FILL SPRAY: Fibrous spray insulations are an innovative use of some traditional blown insulation products or recycled materials all using low-toxicity binders. These loose-fill solutions can be sprayed when mixed with moisture or binding agents. Some are intended for filling cavities while others are designed to adhere to exposed surfaces such as joists and floor pans. Correct installation requires careful management of moisture content and carefully watching the installed density. Cellulose-based solutions such as Green Fiber’s Cocoon System are made from recycled newspaper and incorporate EPA-registered fungicide. Some companies are fine-tuning their blends to emphasize fireproofing and acoustical attenuation along with energy-saving insulation.

SPRAY FOAM: Foam-in-place technology is playing an increasingly important role in establishing a tight building envelope. Historically, most of these products utilized high-density, closed-cell polyurethanes, which involved exposure to potentially hazardous chemicals during application. Today they usually flash their VOCs quickly and become fairly innocuous after a short time. Closed-cell foams are very effective at managing air leakage and can have high R-values of up to 7 per inch. Unfortunately, most still use HCFCs as blowing agents (with some notable exceptions such as SuperGreen).

But there are now a number of non-ozone-depleting, open-cell products available. These open-cell foams have lower R-values, but manufacturing them requires fewer hydrocarbon resources. Some are managing to replace petrochemicals with bio-based raw materials. The Icynene insulation system has a very long track record and is the most widely installed open-cell foam used today. BioBased 501 is a polyurethane foam with a soybean-oil base that uses carbon dioxide as a blowing agent. These products seem to be gaining rapid acceptance as builders look for alternatives to traditional insulation.

SIPS: An alternative to installing traditional insulation, Structural Insulated Panels (SIPs) are typically constructed of OSB sandwiching a foam core. Pros appreciate the ease of assembly and the improved performance SIPs can provide. Typical wall system R-values are from 22 to 30; these walls actually perform remarkably well as they have less framing materials thus reducing thermal bridging. This would eliminate the conventional framing approach and provide a faster and very tight enclosure. Still, these are not perfect either and require some training to install them correctly.

Framing Details
Regardless of the system you choose, remember that structural framing has a significant impact on insulation performance. The space between the studs may be R-22, but the studs, trimmers, headers, and rim joists themselves are only R-7 or R-8. Also remember that complex framing designs increase the building envelope’s surface area, and more surface area means more energy loss. Design the building shell with less surface area,
and you’ll be miles ahead before you even start thinking about insulation.

Most wall insulation is traditionally installed in wood stud cavities, but adding insulation on the outside of the frame can significantly improve building performance if traditional framing is used. Besides adding additional insulation value, insulating the exterior of the enclosure also reduces dew-point potentials in cold climates and condensation potentials in high latent-load cooling climates. Exterior insulation also reduces the thermal bridging effect that studs have in a wall.

Because steel-stud exterior walls lose much more heat than wood-framed walls, they have the additional need to be sheathed in extruded or expanded polystyrene. The Department of Energy specifies the application of a minimum 1- to 2-inch layer over steel framing members to prevent thermal transfers that bypass the insulated cavities. In most climates, I would recommend installing at least 2 to 3 inches of foam if steel studs are being used. Enclosing the box with rigid insulation also can tighten up the envelope and will keep framing materials warmer and drier. Remember, in all but the most extreme climates a house enclosed in foam sheathing should not have an interior polyethylene vapor barrier. (More on this topic in the next issue.)

Put It All Together
With all of these approaches, real success comes from paying attention to the details. When wall and roof assemblies effectively connect with improved insulation products, we achieve synergistic gains. As our industry increases understanding of and respect for the fundamentals of building science, it is leading to many significant product innovations. Keep your eyes and knowledge tuned to improving our buildings’ performance.

INSULATION: PRODUCT REVIEW

Sometimes finding the right insulation can be extremely tricky. Fernando Pages Ruiz wrote a great article for ecohome magazine that lays a comprehensive list and product review of most insulations available:

Insulation represents an inherently green building material because it is designed to save energy. Still, while any insulation is better than none, the many choices present a broad range of benefits, with certain products inherently more ecological than others.

Here is a sampling of the major types of insulation, their properties, and their sustainability beyond simply saving energy.

Fiberglass
Ubiquitous and economical, fiberglass represents the largest share of the market, comprising more than 50% of the insulation installed in the U.S. in 2007, according to the North American Insulation Manufacturers Association (NAIMA). It’s available in loose form for blown-in installation and in blankets, rolls, and batts for compression installation. Depending on density, both blown and stuffed fiberglass products provide R-13 to R-15 in a 2×4 wall cavity. Medium-density fiberglass designed for 2×6 constructions now provides R-21. In a 9?1/2-inch (2×10) cavity, high-density fiberglass can deliver a whopping R-38.
All fiberglass insulation manufacturers use 25% to 40% recycled glass in their products, according to Paul Bertram, director of environment and sustainability for NAIMA. The balance is sand, an abundant natural resource, with chemical binders added to create loft and a cohesive mat in the case of batt-style insulation.

One ecological issue with fiberglass is that glass and sand have to bake at extremely high temperatures to produce fibers. On the flip side, a typical pound of fiberglass insulation “saves 12 times as much energy in its first year in place as the energy used to produce it,” says Bertram.

Most of the health concerns and allegations made about fiberglass insulation have been retracted or disproved. The National Academy of Sciences (NAS) reported in 2000 that epidemiological studies of glass-fiber manufacturing workers indicate “glass fibers do not appear to increase the risk of respiratory system cancer.” NAS now supports the exposure limit of 1.0 f/cc that has been the industry recommendation since the early 1990s. And as of 2001, the International Agency for Research on Cancer (IARC), on which the California standards for Proposition 65 are based, no longer classifies fiberglass as a human carcinogen.

Perhaps the biggest objection to fiberglass batts in green building circles comes from the binders used to glue the glass fibers into a cohesive mat. These binders usually contain formaldehyde, a chemical known to cause sensitivity in certain people and classified as a human carcinogen by the IARC and as a probable human carcinogen by the EPA.

Most manufacturers insist that the low levels of formaldehyde used in manufacturing fiberglass batts makes any health concern exaggerated when compared to many other building products and naturally occurring off-gassing from raw materials, such as wood. In fact, some fiberglass batt insulation with added formaldehyde has gained Greenguard certification.

But if you are concerned, loose fill or blown fiberglass insulation requires no binder, which means no formaldehyde. For those using batts, Johns Manville offers the only fiberglass batt product line with no added formaldehyde. “We don’t consider the formaldehyde binders in insulation to be a big contributor to indoor air pollution, but since we can use alternatives without formaldehyde, why not do our little part to improve the environment?” explains Erick Olson, a senior technical product specialist for Johns Manville.

Any stuffed insulation requires excellent on-site quality control to perform at its rated R-value. A few missed cuts, gaps, or cracks left between batts, and the R-value plummets. Blown and foamed insulation usually provide a more foolproof system to prevent air infiltration, but an excellent sealing job using a well-aimed caulk gun and a few cans of foam sealant coupled with a craftsmanlike batt installation can yield low-cost insulation results comparable to the blown systems.

Non-Fiberglass Batt

Non-fiberglass batts can be made of cotton, sheep’s wool, or mineral (rock or slag) wool. All of the alternative batt insulation products are made almost entirely from recycled or renewable materials. They offer similar thermal performance as fiberglass but at a slight cost premium. They come unfaced and need the addition of a separate vapor retarder in extreme-cold climate zones.

To make them fire resistant and prevent mold and insect infestation, most alternative batt (and cellulose) insulation fibers are coated with ammonium sulfate or borate. Although one manufacturer advertises its product as so safe a child could eat it, both sulfates and borate are used as pesticides and have toxic properties. At a minimum, a respirator should be worn when installing any kind of insulation.

Cellulose

Although the broad category of cellulose insulation includes a variety of products such as granulated cork, hemp fibers, straw, and grains, the most common and readily available cellulose insulation is made almost entirely from recycled newspapers, cardboard, waste paper, and wood pulp. Cellulose insulation is perhaps the best example of a significant recycled product in widespread use. Most is approximately 90% post-consumer recycled waste paper, with fire-retardant chemicals and, in some products, acrylic binders added.

“Mineral fiber materials take at least 25 to 30 times more energy to make than cellulose of equivalent R-value,” says Daniel Lea, executive director of the Cellulose Insulation Manufacturers Association, citing cellulose’s low-intensity manufacturing process and high recycled content.

Nowadays, blown cellulose is applied dry or merely damp, eliminating the extended drying times required for older, “wet” applications. Because of its relative high density and fire suppressants, this recycled newsprint product increases the fire resistance of building assemblies by 22% to 55%, per the Canadian National
Research Council. It also provides a better air seal than fiberglass because of its higher density and slight dampness when applied, which tend to push the material into framing member penetrations.

As with cotton and wool, cellulose is an organic and flammable product that requires added biocides and flame retardants, usually borate and ammonium sulfate. Most cellulose installations are done by contractors using special equipment, but loose fill is also available that anyone can simply pour out of a bag. As with all other insulation products, installers should wear proper respirators as recommended by the manufacturer, especially since some people have sensitivity to newsprint ink. Foam

Although R-values remain close to equivalent across all insulation products, expanding foam has an added benefit because of the excellent air seal it provides. Foams are two-part products that are mixed through a blowing mechanism and sprayed into the framing cavity. The two chemicals react and expand. As the foam expands, it fuses tightly around all pipes, ducts, and wires, creating an airtight seal that yields much higher thermal performance than R-value alone would suggest.

The adhesive quality of foam offers another benefit rarely associated with insulation: High-density foam insulation provides improved structural integrity that helps make a building a little stronger. Nowadays, most foams use HCFCs as blowing agents, which are less destructive to the ozone layer than the old, and now banned, CFCs but still considered environmentally detrimental. Foams that do not use ozone-depleting blowing agents include Icynene, which uses carbon dioxide and water; Air Krete, a foam produced from magnesium oxide (derived from sea water) and compressed air; and BioBased, which uses compressed air.

As a builder of low-cost houses, I look for the least expensive option to achieve the best possible results. For this reason, I often use high-density fiberglass batts coupled with an excellent sealing job. But when my company set out to build a LEED for Homes–certified demonstration house, we chose BioBased insulation as a high-performance alternative.

Depending on market niche, the variety of insulation products available lets a builder distinguish his house as a comfortable, energy-efficient, and environmentally safe place to call home.

**Owens Corning.** The manufacturer says its entire line of fiberglass insulation products has been certified by Scientific Certification Systems to contain an average of 35% recycled content, 5% of which comes from post-consumer sources. ProPink fiberglass insulation carries Greenguard certification, including its highest level with Greenguard Children & Schools product emission standards. 800.438.7465. www.owenscorning.com.

**Demilec.** Sealection Agribalance open-cell, semi-rigid, polyurethane spray-foam insulation contains more than 10% renewable, agriculture-based products, says the firm. The material expands to fill the cavity, sealing cracks, gaps, and voids. It provides an R-value of 4.45 per inch. 877.336.4532. www.demilecusa.com.

**CertainTeed.** Designed for attic areas, InsulSafe SP blown-in fiberglass insulation is manufactured with no formaldehyde and is Greenguard certified. The product offers up to 20% better coverage versus competitors, the company says, with one bag covering up to 67 square feet. InsulSafe SP installed in the attic at 113/4 inches is R-30 and 141/2 inches is R-38. 800.233.8990. www.certainteed.com.

**Advanced Fiber Technology.** AFT cellulose insulation is made from 85% post-consumer recycled newspaper and cardboard. The pulp is ground into a fine, fluffy powder, then treated with primarily boric acid and borax to render it fire resistant. The higher density of this cellulose insulation makes for a tight seal, second only to foam products in blocking air infiltration and sound deadening, says the company. The blown-in insulation provides an R-value of 3.8 per inch. 419.562.1337. www.advancedfiber.com.

**Thermafiber.** Thermafiber mineral wool insulation is made with up to 90% post-industrial recycled content. It exceeds the California purchase specifications for total volatile organic compounds and general emissions with formaldehyde concentrations of 12 ppb, exceeding the California standard of 20 ppb maximum for formaldehyde concentration. Thermafiber can provide high sound-transmission coefficients that improve indoor environmental quality. The product also offers fire resistance of more than 2,000 degrees F for more than five hours, the maker says. 888.834.2371. www.thermafiber.com.

**Air Krete.** The company’s magnesium silicate, cement-based insulation is foamed or pumped into closed cavities. This insulation is purportedly hypoallergenic and popular with chemically sensitive people, the company claims. Since it is not temperature sensitive, it can be installed indoors under any weather conditions and tolerates contact with high-heat sources, such as exhaust pipes, without concerns for combustion. The product is fully recyclable and can be used for soil enrichment. Air Krete has an R-value of about 3.9 per inch. 315.834.6609. www.airkrete.com.
**Icynene.** Icynene water-blown foam insulation expands to 100 times its volume to fill cracks and crevices and minimize air leakage. It carries an R-value of 3.6 per inch. The product also is available in a pour-fill variation that expands upward to 60 times its original volume; it will not expand outward and damage the wall. The pour-fill version has an R-value of 4 per inch. 800.758.7325. www.icynene.com.

**Johns Manville.** Formaldehyde-free MR faced fiberglass batts use a water-based acrylic binder that meets California’s Section 01350 standards. The facing serves as an integral vapor retarder, chemically protected against potential fungi growth. The company claims to obtain its sand from sources close to the manufacturing plant to reduce transportation impacts, and 20% of its recycled content is post-consumer. 800.654.3103. www.jm.com.

**Second Nature.** Sheep’s wool is an insulation product commonly used in Europe and available in the United States through the Internet. A natural insulator, wool has a slightly higher R-value per inch than fiberglass and does not lose its insulating property when wet. It has inherent properties that resist both flame and many insects, but remains susceptible to moths, so it is treated with boron. Thermafleece comes in 2-inch-thick batts cut to friction fit within 16- and 24-inch stud spacing. They carry an R value of 3.8 per inch and can be layered to achieve the desired total R value. www.secondnatureuk.com.

**BioBased 1701 BioBased Insulation.** Unlike some traditional spray-foam insulation products that are petroleum-based and use HCFCs as blowing agents, BioBased 1701 is a soy-based, 100% water-blown, closed-cell polyurethane insulation. It has earned the Greenguard air quality certification. BioBased 1701 has an R-value of 19 at 3½ inches. 800.803.5189. www.biobased.net.

**Bonded Logic.** Ultra Touch cotton friction-fit batt insulation can be used for 16- and 24-inch spacing. The product is made with 85% post-industrial recycled content. The line includes an R-30 batt that fits into 2×6 walls or joist cavities. Cotton insulation offers acoustic properties 36% higher than fiberglass, says the company, only slightly less than mineral wool. 480.812.9114. www.bondedlogic.com.