By Mason Knowles

Balancing Performance & Sustainability

Plastics in construction

Photo courtesy CertainTeed Corp.

When the word “plastic” enters design conversations, PVC (polyvinyl chloride) piping, siding, window frames—maybe even roofing—come to mind. Few consider insulation, moulding trim, wallcoverings, bathroom fixtures, flooring, beams, columns, and doors as derived from plastic, let alone the plastics blended into products for concrete chemicals, wood board, and paint. While this list of products clearly demonstrates plastics are prominent in today's building market, many have yet to recognize the material as an answer for sustainable and green building design.

Photo courtesy Brewster Wallcovering Co.

Below left: Plastic railings and deck materials are available in a variety of configurations to suit many architectural styles.

Right: Vinyl wallcoverings are available in a wide variety of colors and patterns to help set the tone for any room, and can last up to four times longer than conventional paint.

A recent survey of building professionals conducted by NFO World Group for the American Plastics Council (APC), indicates the most important characteristics considered in the selection of a building material are: safety (65 percent), durability (60 percent), and contributing to a healthy environment (59 percent). Unfortunately, the respondents failed to recognize plastics as a strong performer in those areas: only 23 percent listed plastics as easy to maintain, 22 percent rated them high in durability and versatility, and a mere 17 percent recognized plastics as a safe material. This contradiction between perception and reality hinders the adoption of plastics and the realization of their contribution to sustainable design.

Plastics everywhere

As polymers, plastics are made up of chains of many different molecules, such as carbon, hydrogen, oxygen, and/or silicon. The majority of polymers are thermoplastic, meaning they can be formed, heated, and re-formed repeatedly. This property permits easy processing and facilitates recycling.

The construction industry accounts for the single largest end-user of polyurethanes (almost 635,029 t [700,000 tons] per year) in the form of rigid foams, binders, coatings, sealants, and adhesives. Accounting for more than 57 percent of polyurethanes used in construction, rigid foams are used in roofing and wall insulation, foam core panels, insulated doors, and air barrier sealants.

Due to their flexibility and versatility, they can be cut into sheets, slabs, or any desired design, as well as sprayed in place to meet specific building code requirements or custom designs. Polyurethanes are a durable sustainable design solution because they often arrive at the job site as a liquid, which saves on transportation costs and reduces waste.

Polyurethane-based binders, used both with wood and rubber, account for the second largest end-use of plastics. They are used in composite panel products to permanently join strands into oriented strandboard (OSB), hardboard (HB), medium-density fiberboard (MDF) and strawboard, particleboard (PB), and laminated veneer lumber (LVL).

Polyurethane-based sealants are used in joints and openings to prevent the passage of gases, liquids, and solids (dust and dirt). Similarly, polyurethane-based adhesives are used to bond wall and ceiling panels to the structural frame, floor joists to the sub-floor decking, and structural end, side, and interior shear walls to gypsum wallboard.

Polyurethane elastomers are used in the manufacture of outdoor and indoor athletic surfaces, as well as insulating windows, creating a thermal break and barrier to prevent heat loss and condensation build-up on the interior of the frame.

Spray polyurethane foam (SPF), used as roofing and insulation system applications, conforms to the surface to which it is applied

Test Your Knowledge *of* Plastics

Questions

1. The term "resource conservation" can be defined as:

- **a.** The planned management of natural resources to optimize their utility.
- **b.** Doing more with less.
- **c.** Both A and B.
- **d.** None of the above.

2. Which of the following characteristics make plastics the ideal choice for manufacturers looking to minimize the amount of materials and energy used to make a product?

- **a.** Light weight.
- **b.** Durable.
- **c.** Formable.
- **d.** All of the above.

3. Which of the following items can be made with recycled plastics?

- **a.** Carpets, clothing, and textiles.
- **b.** Playground equipment, film, and air-bubble cushioning.
- **c.** Neither A nor B.
- **d.** Both A and B.

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4. The National Research Council (NRC) of Canada performed a two-year study to gage the performance of rigid foam plastics used as exterior basement insulation in contact with the ground. The research concluded the thermal performance of the specimens:

- **a.** Was maintained.
- **b.** Slightly affected.
- **c.** Totally depreciated.
- **d.** Decreased when in contact with water.

5. Plastic building and construction materials have contributed to saving over 492,922 million J (467.2 million Btu) of energy over a one-year period. This is the equal to the energy needs of _____ households.

- **a.** 5.2 million
- **b.** 4.6 million
- **c.** 1.3 million
- **d.** 9.6 million

6. True or False: Inadequate air barriers and leaky building envelopes will not contribute to uncomfortable indoor environments, high energy costs, and mold infiltration.

and forms a seamless layer of insulation. Since SPF fills in gaps and seams during application, it is increasingly being used as an air barrier. SPF exhibits a high degree of sustainable characteristics, owing primarily to the minimal energy used in manufacturing the lightweight plastic, as well as decreased energy and transportation costs.

Energy studies performed by Texas A&M on their own roofs (presented at Texas A&M SPF Roofing Experience by Sam Cohen, PE, 1994) show the energy cost reductions obtained by applying SPF to more than 743,224 m^2 (8 million sf) of roofing paid for the cost of the retrofit in a little over three years. SPF adhesives offer exceptional wind up-lift resistance, exceeding 3447 kPa (500 psi) over some substrates.

Polyisocyanurate (polyiso) laminate boardstock, used primarily in roofing and wall insulation, accounts for 85 percent of the total usage of rigid polyurethane foam in construction applications. It offers high insulation value—ranging between 5.6 to 7.9 R-value per 25 mm (1 in.)—as well as good moisture, fire, and impact resistance.

Another area in which plastics are becoming more commonly specified is the growing use of expanded polystyrene (EPS) in insulated concrete forms (ICFs). In this application, EPS provides lower energy bills, decreases noise by as much as one-third compared to ordinary insulated frame walls, and increases ease of construction and design flexibility.

Selecting EPS as a sustainable building element is increasing with the variety of products now available, such as geofoam (used as lightweight fill, thermal insulation, compressible inclusion, drainage, noise and small-amplitude vibration damping, and structural and soil stabilization). Plastic geofoams have a density that is only one to two percent of the density of soil, yet can be designed to be sufficiently strong and stiff enough to support road, rail, and aircraft loading.

The use of polycarbonate windows offers designers another alternative. Boasting a lower thermal conductivity than glass, use of this product reduces heating and cooling energy needs while providing additional high-strength, shatter-resistance during dangerous storm or hurricane weather.

Still, the plastic most commonly used in building

A study by Franklin Associates found plastic products use less energy than alternative materials.

Plastic Resin	Alternative Product and End-Use	Energy Savings in Trillion J (Btu)	
Polyurethane	Rubber for carpet underlay	20,574	(19.5)
PVC	Ceramic tile or linoleum for flooring	14,982	(14.2)
HDPE or PVC	Metal for gutters and downspouts	1,477	(1.4)
Polystyrene or polyurethane	Fiberglass for insulation	42,835	(40.6)
Polystyrene or PVC	Metal or wood for lighting components	29,964	(28.4)
PVC, unsaturated polyester	Metal or wood for paneling and siding	27,009	(25.6)
ABS, HDPE, polystyrene, PVC unsaturated polyester	Metal, concrete, or vitrified clay for pipe, fittings, and conduit	348,696	(330.5)
Unsaturated polyester	Metal/porcelain for showers/tubs	5,064	(4.8)
PVC	Metal or wood for window units	2,005	(1.9)

Photo courtesy CertainTeed Corp.

Vinyl siding requires little maintenance, remaining attractive for years.

applications is vinyl, or PVC. This form of plastic can be forced through a mold to form long lengths of product, such as siding; injected into a three-dimensional mold to create electrical outlet boxes; put through a calendering process to produce film and sheet products for flooring or wallcovering; thermoformed for rigid uses such as shower trays; and dispersed in a solution and coated to make products like carpet backing, or vinyl-coated products like closet shelving.

Regardless of the end product, there is little that challenges vinyl's versatility, durability, and possible textures, colors, and shapes. In the United States, two-thirds of all vinyl is used in building and construction applications, and while new applications continue to evolve, PVC continues to benefit the environment.

Green facts

The vinyl resin manufacturing process is essentially closed, so nearly all waste is recycled. In fact, more than 99 percent of all vinyl manufactured ends up in a finished product. Another life-cycle assessment determined vinyl production accounts for a fraction of one percent of all U.S. oil and gas consumption. The same study compared the manufacturing processes for vinyl and metal-clad windows and determined vinyl used approximately three times less energy—equating to nearly 2110 trillion J (2 trillion Btu) of energy per year in the United States—which is enough to meet the yearly electrical needs of 18,000 single-family homes.

Beyond the manufacturing and transportation processes, many vinyl building products save energy for the end-user. For example, vinyl transfers heat more slowly than metal-clad window frames, so utility costs are kept low.

Single-ply vinyl roofs are also energy efficient. Research from the Environmental Protection Agency (EPA), the National Aeronautics and Space Administration (NASA), and the Federal Department of Energy (DoE) shows reflective roofs—plastic assemblies that bounce sunlight and radiant heat away from a building—lower a building's air-conditioning costs by up to 40 percent (*Green House,* APC).

Changing mindsets

Mindsets are often difficult to alter—such as the notion of "natural" materials or products compared with "synthetic" materials or products. Mahogany is good material, but it is too expensive and takes too long to grow to be practical on a mass scale. However, synthetic or synthetically modified materials provide the durable and cost-effective solution not always possible with stand-alone natural products. As such, one sustainable design solution is to use plastic binders with wood chips from trees that grow rapidly.

Specifiers are facing increasing pressures to use/not use certain products. In a handful of states, proposed regulatory language and tax incentives have already been introduced to incorporate certain products based on "green" attributes. However, specifiers are cautioned to focus less on product and more on the sum of the products as a system.

Sustainable design goes far beyond simply creating products that benefit consumers with cleaner air, cost savings, and durability. Rather, effective sustainable design illustrates a full-systems approach of products in the environment, and their interaction with other products.

A systems approach determines the energy requirements of a product. This means determining energy consumed at each stage of a product's life cycle, beginning at the point of extraction from the earth, through processing, manufacturing and fabrication, end-use, and disposal. End-use can account for as much as 90 percent of a product's impact on the environment. Transportation of materials and products through each process step must also be calculated.

In terms of energy used during production, only about four percent of the United States' energy consumption is actually used to produce plastic raw materials, including feedstock. Often, less energy is used to convert plastics from a raw material into a finished material than comparable products.

Test Your Knowledge of Plastics

Answers

1 – A: Resource conservation is the planned management of natural resources to optimize their utility, and typically includes efficient usage in their original application, reuse, and recycling. Plastic products employ the elements of resource conservation throughout their life cycle.

2 – D: Lightweight, durable, and formable, plastics are becoming the ideal choice for manufacturers looking to save energy, money, and time.

3 – D: Carpets, clothing, textiles, playground equipment, film, and air-bubble cushioning can all be made from recycled plastics. Some other common products that can be made from recycled plastics include battery casings, industrial fibers, packaging products, bags, motor oil bottles, decking, and marine pilings. (Check whether these recycling options are available in your community.)

4 – A: The foam insulation showed stable thermal performance in the soil over the 24-month period. In fact, researchers noted an improvement in the thermal performance during the second year. The following parameters of expanded polystyrene (EPS) products appeared to have little or no effect on its R-value: duration of exposure, mean temperature of the specimen, water movement at the outer surface, density of product, and freezing cycles.

5 – B: Franklin Associates found approximately 4.6 million households use that amount of energy. The 11 states cited in the report that would make up this total are Nebraska, Utah, Nevada, Maine, Indiana, Hawaii, Montana, South Dakota, North Dakota, Arkansas, and Wyoming.

6 – False: A combination of plastic non-woven fabric and foam plastic sheathing will typically help prevent and reduce air penetration by 10 to 50 percent, which translates into improved indoor air quality (IAQ) and reduced heating and cooling costs. It also helps prevent the decay of building materials due to mold, bugs, and rot.

The most common misconception about plastics is they are cheap and flimsy. Today's plastics comprise sophisticated compounds and are designed with sustainability in mind. They are easy to clean, last longer than many natural materials, and often leave a lighter environmental footprint.

Resources

- *Annual Survey of Resin Used by Market*, APC 2000.
- *History of Plastics*, APC.
- *Plastics Used in Building and Construction*, APC, for publication in 2002.
- "Insulated Concrete Walls Save Energy: Side-by-side Study Compares Insulated Concrete, Wood, and Steel-Framed Homes' Performance." *Permanent Buildings & Foundations*, January, 2002.
- "Full Speed Ahead." *Engineering News-Record*, Nov. 2, 1998.
- Structural Insulated Panel Association (SIPA).
- "A Comparison of Energy Consumption by the Plastics Industry to Total Energy in the U.S.," Franklin Associates, 1995 update.

About the Author

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Did You Know?

Foam plastic insulation controls unwanted air infiltration—in and out of the building—a problem wasting potentially close to 40 percent of every heating and cooling dollar. Closed-cell foam plastic insulation can be efficient in a wide variety of temperature and humidity conditions.

Vinyl window frames require three times less energy to manufacture than aluminum window frames, saving the United States around 21 trillion kJ (2 trillion Btu)—enough to meet the yearly electrical needs of 18,000 single-family homes.