



American
Plastics
Council®

The Technology of Plastics

One in a
Series



Composites

as High Performance Building Solutions

Architects, designers, builders and property owners are continuing to discover the many advantages that composites can provide as construction materials, including light weight, durability, corrosion resistance, high strength, and low maintenance requirements. Here, we'll explore the high-performance characteristics and varied applications of these fiber-reinforced plastics in today's modern construction and renovation projects.

Composites get much of their versatility from the fact that they can be engineered to provide specific performance characteristics. Technically known as fiber-reinforced plastics or fiber-reinforced polymers (FRP), composites are generally comprised of two distinctly different components: a reinforcement fiber and a polymer binder (often called a matrix).

The size, shape, proportional weight or volume and material of the reinforcing fibers typically determine the composite's mechanical properties, such as stiffness and strength, while the type and proportion of the resin matrix lends the finished composite its physical characteristics, such as toughness and resistance to impact.

In each case, the composite is

designed to provide a combination of properties that are superior to the properties provided by either ingredient alone. Fillers or additives also may be used to lend the final composite special properties, such as UV resistance or fire resistance.

By carefully manipulating the composition and processing conditions, scientists can produce individual composites with a specific combination of properties designed to suit a particular application.

Advances in composite formulations and manufacturing technology offer exciting opportunities to custom-design high-performance properties into a wide variety of building applications.

High strength and light weight are two benefits that often drive the use of these engineered products, but other properties, like corrosion resistance or durability, may represent the deciding factor in certain building applications. In many residential and commercial applications, composites are used by themselves; in others, they're used to augment traditional materials.

Unique Materials

Designers of composites can choose from a wide variety of resin systems and fiber reinforcements when making a specific product. Resins, also known as binders, are typically thermoset plastics that serve as the glue holding the reinforcing fibers together in an orderly fashion. The fibers, which are embedded in the resin matrix, are structured to overlap and help transfer the load within the composite structure. Usually manufactured using a molding process, the combination of fibers and resin matrix cures into a solid laminate.

The most commonly used resins are polyester, vinyl ester, modified



Photo courtesy Special-Lite

Aluminum/composite hybrid flush doors can be made with plastic face sheets with a wood grain texture.

Design Parameters of Composites

The attributes of composites construction materials, like strength, weight, and stiffness, can be varied to a significant degree by the choice of materials used for the polymer matrix and reinforcing fibers, the concentrations of each component, and the manufacturing techniques employed. Here are some of the performance characteristics that designers seek to impart to composites materials by their choices:

- Light weight
- Rapid installation ability
- Low maintenance
- Durability
- Corrosion resistance
- Weather resistance
- High impact strength
- Directional strength
- High dielectric strength
- Nonmagnetic properties
- Dimensional stability
- Customized surface finish

acrylic, epoxy, phenolic, and urethane. Each of these resin types imparts specific performance characteristics to a composite, such as corrosion resistance or high strength. The resin system is selected based on the functional requirements of the product and on cost considerations.

The structural properties of a composite depend primarily on the type of fibers used. While the vast majority of composites are made using glass fibers, carbon, aramid, or boron fibers can also be specified when certain physical characteristics are needed.

All of these fiber types impart stiffness and strength to the finished composite, and can control, to varying degrees, just how lightweight the end product is. A wide range of properties and performance levels can be achieved to match the requirements for a specific application.

Natural Fibers

While the fibers mentioned above are typically inorganic, agricultural and wood fibers have also generated interest in the last decade, especially in the housing sector. Although polyethylene, PVC, and polypropylene are the dominant polymers used with natural fiber composites, natural fibers can also be used with phenolics, polyester, polystyrene, polyurethane and other polymer matrixes.

Many composite building products are now produced by embedding natural fibers derived from the bast, or outer stem, of certain plants like wheat straw fiber, flax, jute, kenaf, sisal, hemp, and coconut, in a polyester or polypropylene matrix. The moderate mechanical properties of natural fibers typically prevent them from being used in high-performance applications, but their low specific weight results in relatively high specific strength and stiffness, and is

generally a benefit for parts designed for bending stiffness.

Another natural fiber, wood, is used primarily in composite versions of building products such as decking, window and door profiles, decorative trim, railings and panel products. These products can contain anywhere from 30% to 70% wood, depending on



Photo courtesy Trex Co.

Wood-plastic composites are becoming increasingly popular in outdoor applications due to their durability and weather resistance.

the application, with about 50% being typical. Regardless of the proportion, the wood fibers used in these composites most often take the form of a particulate (i.e., "wood flour"), rather than the longer individual fibers commonly used with inorganic-fiber composites. Commonly used species include pine, maple and oak.

The polymer matrix or resin used in wood-fiber composites can consist of: polyethylene, common in external building components and being investigated for building profiles; PVC, historically used in window manufacture and now being used in decking as well; as well as polystyrene and acrylonitrile-butadiene-styrene (ABS). Some manufacturers use other thermoset resins to produce specialty composites with high wood content.

As with inorganic-fiber composites, small amounts of other materials can be added to wood-plastic composites to improve processing and performance. Additives may include coupling agents, light stabilizers, pigments, lubricants, fungicides, and foaming agents.

Composites as Building Materials

Lightweight and corrosion-resistant composite materials compete with traditional materials in numerous residential, commercial, and industrial construction applications, including pipe, sheet piling for retaining walls, shingles and concrete reinforcements (such as rebar). If a structural element, such as a wall or beam, can benefit from reinforcement, then FRP composites could present a strong solution. Typical projects that lend themselves to the advantages of composites include decks, walls, and roofs.

Composites are used in prefabricated, portable and modular buildings, as well as for exterior cladding panels, which can simulate masonry or stone. In interior applications, composites find application in shower enclosures



Photo courtesy Tom Murphy

Thin-set terrazzo, a composite material, tends to crack less than traditional flooring products.

and trays, baths, sinks, troughs and spas. Vanity units, bench tops and basins can be made from cast composite products. Each type of composite brings its own performance characteristics. The following sections are highlights of specific applications.

Composite Panel and Lumber Products

Polyurethane-based binders are used to make composite panels in a variety of configurations, including oriented-strand board (OSB), hardboard (HB), medium-density fiberboard (MDF) and



OSB panels meet the requirements of a wide variety of building codes.

strawboard, particleboard (PB), and laminated veneer lumber.

OSB, often used as structural sheathing, flooring and roofing in residential construction, is made by coating strands of wood with resin and then pressing them together at high temperature and pressure to form panels. By orienting the milled wood strands in layers, with each successive layer roughly perpendicular to the previous layer, OSB panels can exhibit substantial structural strength per unit thickness, allowing them to meet the requirements of a wide variety of building codes for specific applications.

Milled strands and veneers also can be used to fabricate engineered

lumber that can replace dimensional sawn lumber in many applications. If strands are milled at longer lengths than those used in OSB, and then aligned longitudinally across the entire cross section, they can be formed into long-strand lumber (LSL). Long, narrow veneer strips can also be layered along their length to form laminated-veneer lumber (LVL). Properly manufactured, both LSL and LVL usually offer strength at least equivalent to that of sawn lumber of similar cross-section, and can be fabricated in longer lengths than are commonly available with the equivalent sawn lumber.

Another structural component, I-joists, are comprised of an OSB web integrally bonded to LSL, LVL or sawn 2 x 4 flanges. I-joists offer an alternative to sawn lumber joists in many construction applications. First, engineered I-joists typically weigh less than equivalent sawn lumber joists of the same length. Further, because their length is limited only by the size of manufacturing equipment and shipping considerations, rather than the height of a natural tree, I-joists can be produced in longer lengths than the



Composite fencing offers a lower and more durable alternative to traditional materials.

typically available lengths of conventional sawn lumber. Longer I-joists can help increase building spans—so architects have more design freedom—and, in some cases, longer spans might possibly help to reduce the number of intervening support walls or columns.

Decking, Fencing and Railings

Wood-plastic composites (WPCs) are commonly used in exterior decking and moldings, doorjambs, fencing, and other applications where durability is an important performance attribute. When properly manufactured and installed, WPC lumber generally will not rot, crack, warp, or splinter in most normal U.S. climatic conditions.

Typically low maintenance, long lasting, stain resistant, waterproof, UV resistant, and impervious to insects, composites can be made strong enough for applications such as load-bearing deck boards, and they tend to have significantly greater dimensional stability and a lower coefficient of expansion than solid plastics. Wood fiber, wood flour, and rice hulls are common organic fillers used in these applications.

Photo courtesy CertainTeed



Composite outdoor living products are among the fastest growing applications in the building products industry.

Coextruded wood composite railings—typically comprised of a core of PVC or ABS resin and wood fiber capped by a weatherable PVC or acrylonitrile-styrene-acrylate (ASA) protective layer—are increasingly being offered as an additional measure of customization for contractors and homeowners. Along with a wide variety of color offerings to complement composite decks, these capped composite railings offer good water, stain, fade, and UV resistance.

Window and Doors

PVC is often used as the thermoplastic matrix in window applications, though other plastics are used, too. The fiber used in windows and doors is usually 80- to 200-mesh wood fiber, which produces a wood-filled PVC that is gaining favor because of its thermal stability, moisture resistance, and stiffness.

In new exterior applications, both vinyl and polyolefin (polyethylene and polypropylene) resins have been combined with wood flour to form exterior trim that resists rot and weathering. The resulting material can be molded into a wide range of designs that typically do not require painting or the use

of special cleaning agents. At least one window manufacturer is creating such trim by combining the post-industrial waste from both its wood and vinyl window manufacturing operations.

There is also a growing trend toward using high-end composites for doorjambs. By eliminating some of the performance concerns of commonly used materials, wood-composite doorjambs can offer a complete, virtually maintenance-free system.

Another common type of composite structure - sandwich construction - combines a lightweight core material with laminated composite skins. Doors made of FRP skins surrounding rigid polyure-

thane foam or expanded polystyrene core materials are currently available for both residential and commercial building construction. These composite-sandwich doors offer high specific strength and stiffness, low weight, impact resistance and uniform smooth or textured surfaces. The core stabilizes the facings and carries most of the shear load. A low-density core made of honeycomb or foam materials can provide structural performance with minimum weight. Other considerations, such as sound insulation, heat resistance, and vibration-damping, dictate the choice of core material.

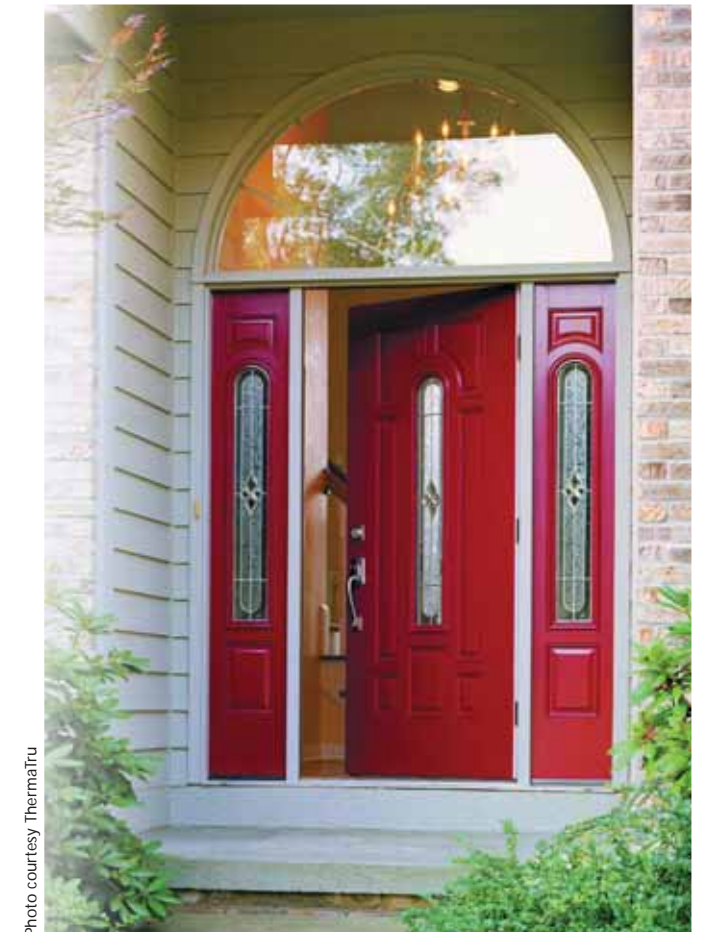


Photo courtesy ThermoTuff

The growing use of composite door products has validated their strength, energy-efficiency and acoustic value.



SIPs help reduce air infiltration in comparison to wall assemblies made of traditional materials.

Walls

Another kind of sandwich is finding its way into residential and commercial construction as well. Structural insulated panels (SIPs), featuring a core of expanded polystyrene (or in some instances, polyisocyanurate) sandwiched between two thin slices of OSB, are strong, lightweight building products that can be designed to have exceptional insulation properties. For example, spray polyurethane foam (SPF) can be used in wall assemblies to increase the racking loads. The National Association of Home Builders (NAHB) have performance results for racking loads from 1992 for SPF-wood-stud panels with 16-inch spacing, showing a 200% increase for panels with vinyl sheathing and an 83% increase for panels with plywood sheathing. NAHB also reports performance results for racking loads in 1996 for SPF-metal wall panels, showing over 100% increase in for panels with drywall sheathing and a 25% increase for panels with OSB sheathing.

Because they are manufactured components, SIPs panels can be delivered to the job site sized for a specific application, with wiring chases and provisions for plumbing rough-in machined or molded into the foam core and the OSB outer panel. Contractors use SIPs in floors, walls, and roofs of residential and industrial buildings.

Composite materials are also being used in renovation applications to help strengthen beams, slabs, walls, columns, chimneys, and other structural elements that have been subjected to deterioration, additional service loads or excessive deflection caused by change in use, construction or design defects, code changes and seismic retrofit.

Wrapping masonry in fiber composite materials can significantly increase its strength. This is particularly important in many communities where seismic codes have been tightened and masonry and concrete walls must be upgraded to meet them. The advantages of FRP materials

lie in their high tensile strength, low weight, and their ability to conform to varying shapes. The growing use of FRP composites in repair and retrofit of concrete and masonry structures has opened the door for similar applications in strengthening wood beams.

Roofs

A number of manufacturers offer roofing shingles made of both post-industrial and post-consumer recycled rubber, recycled plastic, and cellulose fiber. Bound together with polymer adhesives, these shingles can be made to look like cedar shakes or slate tiles, as well as standard asphalt shingles. They may help to lower building energy consumption, while providing long, virtually maintenance-free service life.

Pipes

Glass-reinforced plastic (GRP) pipe is used for the transport of water and wastewater in pressure and non-pressure systems. GRP is a filament-wound, structural composite made with glass fiber and polyester resins. The pipe is lightweight, corrosion resistant, and designed for ease-of-



Bound together with polymer adhesives, composite roofing shingles provide long service life.

installation. Its corrosion resistance can give GRP pipe a long, effective service life with low maintenance costs while making it a strong candidate for piping applications in environments with acidic soil content.

Kitchens and Baths

Cast polymers, which encompass cultured marble, cultured granite, cultured onyx and solid surface products, are chemically bonded and mineral-filled materials used in a wide range of household and commercial applications. Some of these applications include countertops, vanities, shower receptors, bathtubs, enclosure sets, fireplace surrounds, windowsills, wall panels, floor tiles, whirlpool baths and molding accents.

Cast polymers are strong and can be less brittle than some traditional materials. The manufacturing process permits a design latitude and complexity of shape in the finished product that can be difficult to achieve with many alternative products.

Moreover, cast polymer products resist mildew and stains, and they are easily cleaned with non-abrasive cleaning agents. The one-piece, seamless construction of cast polymer is easy to maintain and can be resistant to breakage.

Specially formulated unreinforced polyester resins, known as gel coats, can improve the impact and abrasion resistance, as well as the surface appearance, of the final product. These are applied to a mold surface and gelled before lay-up of the composite. In the tub and shower market, gel-coated fiberglass products vie with glass/acrylic units made with poly-



Cast polymer countertops are easy to maintain.

methyl methacrylate.

Thermoset-based solid surface materials used in kitchen countertops and bath products are produced with high performance resin systems, such as acrylic and unsaturated polyester, formulated with a very high content of fillers, pigments and catalysts. This mixture is cast into molds that form the matrix into either flat panels or customized shapes. The finished product can be machined like wood, routed to make decorative edging, and precisely cut and bonded to fit nearly any surface shape.



Solid surface materials used in kitchen countertops and bathroom products are made with high-performance resins.

Conclusion

Increasing interest in high-performance building solutions will continue to drive the growth of composites in new construction and renovation, especially residential housing applications. Composites differ from traditional materials in that the combination of their distinctly different components can make new high-strength, lightweight materials with corrosion resistance, long-term durability and low maintenance requirements. They also can offer design flexibility, good vibrational damping, resistance to fatigue and to temperature extremes. Skilled designers and fabricators understand composites' unique properties and performance capabilities and are able to develop custom-designed products that optimize material performance. The unique blend of properties designed into the final product can allow designers and manufacturers to substitute high performance composites for many traditional materials.

Finding Plastics Resources Online

POLYSTYRENE INSULATION

Expanded Polystyrene [EPS] Molders Association (EPSMA)
www.epsmolders.org

Insulating Concrete Form [ICF] Association
www.forms.org

Structural Insulated Panel [SIP] Association (SIPA)
www.sips.org

Exterior Insulation Finish Systems [EIFS] Industry Members Association (EIMA)
www.eima.com

Expanded Polystyrene Resin Suppliers (ERSC)
www.americanplasticscouncil.org/apc/about_apc/ersc.html

Extruded Polystyrene Association
www.xpsa.com

POLYURETHANES

Adhesives and Sealant Council (ASC)
www.ascouncil.org

Alliance for the Polyurethanes Industry (API)
www.polyurethane.org

Metal Construction Association (MCA)
www.mca1.org

Alliance for Flexible Polyurethane Foam (AFPF)
www.afpf.com

European Diisocyanate and Polyol Producers Association (ISOPA)
www.isopa.org

Polyisocyanurate Insulation Manufacturers Association (PIMA)
www.pima.org

Polyurethane Foam Association (PFA)
www.pfa.org

International Isocyanate Institute (III)
www.diisocyanates.org

Polyurea Development Association (PDA)
www.pda-online.org

Polyurethane Manufacturers Association (PMA)
www.pmahome.org

PLASTIC PIPING

Plastic Pipe Institute (PPI)
www.plasticpipe.org

American Society of Mechanical Engineers (ASME)
www.asme.org

American Society of Plumbing Engineers (ASPE)
www.aspe.org

American Water Works Association (AWWA)
www.awwa.org

Plastic Pipe and Fittings Association (PPFA)
www.ppfahome.org

International Association of Plumbing and Mechanical Officials (IAPMO)
www.iapmo.org/iapmo

Canadian Institute of Plumbing and Heating (CIPH)
www.ciph.com

Uni-Bell PVC Pipe Association
www.uni-bell.org

VINYL

The Vinyl Institute
www.vinylbydesign.com or
www.vinylinfo.org

Resilient Floor Covering Institute
www.rfci.com

Chemical Fabrics and Film Association
www.chemicalfabricsandfilm.com

Vinyl Siding Institute
www.vinylsiding.org

Vinyl Council of Canada
www.cpia.ca/vinyl

European Council of Vinyl Manufacturers
www.ecvm.org

Wallcoverings Association
www.wallcoverings.org

SPRAY POLYURETHANE FOAM

Spray Polyurethane Foam Alliance (SPFA)
www.sprayfoam.org

Roof Consultants Institute (RCI)
www.rci-online.org

Insulation Contractors Association of America (ICAA)
www.insulate.org

National Roofing Contractors Association (NRCA)
www.nrca.net

Roof Industry Educational Institute (RIEI)
www.riei.org

RELATED ASSOCIATIONS AND ORGANIZATIONS

American Architectural Manufacturers Association (AAMA)
www.aamanet.org

Canadian Plastics Industry Association (CPIA)
www.plastics.ca

Plastics Technology
www.plastics-technology.com

American Chemistry Council (ACC)
www.americanchemistry.com

Chlorine Chemistry Council (CCC)
www.c3.org

Partnership for Advancing Technology in Housing (PATH)
www.pathnet.org

ASTM International
www.astm.org

International Code Council (ICC)
www.iccsafe.org

Society of Plastics Engineers (SPE)
www.4spe.org

FM Global
www.factorymutual.com

National Association of Home Builders (NAHB)
www.nahb.org

Society of the Plastics Industry (SPI)
www.plasticsindustry.org

British Plastics Federation (BPF)
www.bpf.co.uk

NSF International
www.nsf.org

Underwriters Laboratories
www.ul.com

Building Environment and Thermal Envelope Council (BETEC)
www.nibs.org/betechm.html

National Institute of Building Sciences (NIBS)
www.nist.gov

Building for Environmental and Economic Sustainability (BEES) provides users with direct comparisons between environmental performance and life-cycle cost.
www.bfrl.nist.gov/oe/bees.html

The Consortium for Moisture Management for Exterior Wall Systems (MEWS) is developing guidelines for wall systems to meet long-term performance and durability for various climate zones.
irc.nrc-cnrc.gc.ca/bes/mews/index.html

MOIST predicts the one-dimensional transfer of heat and moisture, allowing users to investigate the effects of various parameters on moisture accumulation within layers of construction.
www.bfrl.nist.gov/863/moist.html

WUFI is an advanced hygrothermal model that solves the coupled heat and moisture transport in building envelope systems, such as walls and roofs.
www.eere.energy.gov/buildings/tools_directory/software/wufi-ornl-ibp.html



American Plastics Council
1300 Wilson Boulevard, 13th Floor
Arlington, VA 22209
T: 703-741-5626 • F: 703-741-6626

www.greenbuildingsolutions.org