Why Fiber Reinforced Polymer (FRP) Structural Shapes Have Become a Material of Choice

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In today's world of focus on structures that can be erected easily and quickly, provide a long service life, and generate fast economic pay-back, FRP structural shapes, plate and building products are rapidly gaining recognition. Structural engineers, as well as architects, constructors and owners, are making pultruded FRP shapes a material of choice on many projects. No longer considered an unproven, "exotic" alternative, FRP shapes have very high strength-to-weight ratios and extended life cycles when compared to conventional materials. These materials can improve constructability, lower field installation costs, enhance serviceability and sustainability resulting in less maintenance and will not rot or corrode in most environments.

What Fiber Reinforced Polymer (FRP) Pultruded Products Are

FRP pultruded structural shapes, plates, and building products are produced by the "pultrusion" process where reinforcing fibers (placed in pre-engineered laminates by specially designed tooling) are pulled through a liquid resin matrix (resins, fillers, and special property defining additives), cured in a heated die, and cut to required lengths. The most widely used reinforcements are glass and glass/carbon hybrids. Common resin systems are polyester, vinyl ester and epoxy. Some products incorporate other reinforcements such as aramid fibers and/or other resins such as polyurethane or phenolic resin systems. Variations in physical and material properties can be achieved by the changing of the types of resins and additives, and the types, forms and fiber architecture of the reinforcements.

The structural engineer can take advantage of the characteristic properties of pultruded FRP structural products by properly selecting the material and products specific to his or her project requirements. Characteristic properties include:

- corrosion resistance in high acidic environments,
- thermal and electrical non-conductivity,
- lightweight (weighs 80% less than steel),
- high strength,
- dimensional stability,
- low maintenance, and
- custom colors.

Fabrication of FRP Pultruded Products

The fabrication of pultruded FRP structural products is very similar to fabricating structural timber structures. Standard woodworking saws, drills, and sanders are used. Connections and joints are generally made with mechanical fasteners such as stainless steel bolts and rivets or fiberglass threaded rods and thermoplastic cast nut systems. Adhesives can be incorporated in connections to provide redundancy, and to distribute forces and stresses evenly. Many building products incorporate interconnected joints or mechanical splines with adhesives to produce rigid interlocking assemblies.

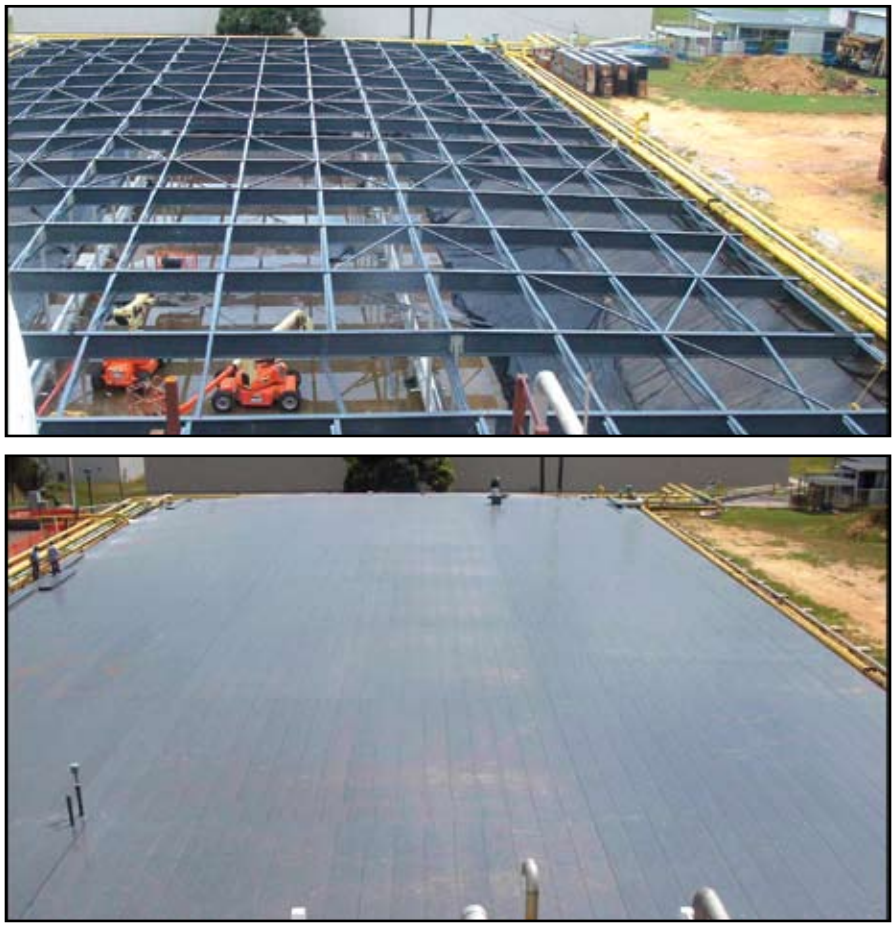

Figure 1: Fiberglass Structural Shapes were used for the structural framework in this pharmaceutical waste treatment plant in Puerto Rico. FRP building panels were installed as odor control covers. FRP was chosen due to its ability to resist corrosion and be easily and quickly installed.

Where FRP Pultruded Products Have Been Utilized

Utilizing the material's mechanical and physical properties and characteristics, structural engineers have incorporated FRP structural components, products, and systems into extremely varied and wide ranges of applications and projects. In each application and project where these products are used, the design team has taken advantage of the characteristics of the products as compared to conventional materials (including structural steel, stainless steel, aluminum, concrete and timber). *Table 1 (page 24)* lists types of construction markets and applications and the serviceability, constructability and sustainability characteristics of FRP pultruded products as compared to conventional materials. In these applications, pultruded fiberglass products have proven

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Table 1: Pultruded FRP Structural Products as Compared to Conventional Materials[1] for Various Applications.

CONSTRUCTION MARKET APPLICATION	SERVICEABILITY					CONSTRUCT-ABILITY			SUSTAINABILITY			
	CORROSION RESISTANT	ELECTRICAL NON-CONDUCTIVITY	STRENGTH	STIFFNESS	IMPACT RESISTANT	LIGHTWEIGHT (HANDLING)	LIGHTWEIGHT (ADJACENT SUPPORT)	FIELD FABRICATION (COSTS)	FREEZE THAW RESISTANT	COLOR FAST	INSECT RESISTANT	ROT/DECAY RESISTANT
PETRO-CHEMICAL/CHEMICAL	+	+	E	E	+	+	+	+	E	+	+	+
ACCESS WALKWAY SYSTEMS	+	+	E	E	+	+	+	E	E	+	E	E
TANK FARM PLATFORMS/RAISED FLRS	+	+	E	E	+	+	+	+	E	+	E	E
HAZARDOUS MATERIAL STORAGE	+	+	E	E	+	+	+	+	E	+	E	E
SPILL CONTAINMENTS	+	+	E	–	E	+	+	+	+	+	E	E
ENCLOSURES (EQUIPMENT/PERSONNEL)	+	+	E	E	+	+	+	E	E	+	+	+
PIPE SUPPORTS/RACKS	+	+	–	–	+	+	+	+	E	+	E	E
COVER SYSTEMS	+	+	E	E	+	+	+	E	E	+	E	E
WATER TREATMENT FACILITIES	+	+	E	E	+	+	+	E	E	+	E	E
ACCESS WALKWAY SYSTEMS	+	+	E	E	+	+	+	E	E	+	E	E
BAFFLE SYSTEMS	+	+	E	E	E	+	+	E	E	+	+	+
COVER SYSTEMS	+	+	E	E	+	+	+	E	E	+	E	E
ENCLOSURES (EQUIPMENT/PERSONNEL)	+	+	E	E	+	+	+	E	E	+	+	+
PIPE SUPPORTS/RACKS	+	+	–	–	+	+	+	+	E	+	E	E
COVER SYSTEMS	+	+	E	E	+	+	+	E	E	+	E	E
POWER GENERATION COOLING	+	E	E	E	+	+	+	E	E	+	+	+
COOLING TOWER STRUCTURE	+	E	E	E	+	+	+	E	E	+	+	+
ACCESS WALKWAY SYSTEMS	+	E	E	E	+	+	+	E	E	+	+	+
DECKING SYSTEMS	+	E	+	E	+	+	+	E	E	+	+	+
PIPE SUPPORTS/RACKS	+	+	–	–	+	+	+	+	E	+	+	+
WIND TURBINE BLADES	+	+	–	–	+	+	+	E	E	+	E	E
POLLUTION CONTROL	+	+	E	E	+	+	+	E	E	+	E	E
COVER SYSTEMS	+	+	E	E	+	+	+	E	E	+	E	E
CONTAINMENT SYSTEMS	+	+	E	–	E	+	+	+	+	+	E	E
ACCESS WALKWAY SYSTEMS	+	+	E	E	+	+	+	E	E	+	E	E
DE-SULPHURIZATION/DEMISTER STR.	+	+	E	E	+	+	+	+	E	+	E	E
ELECTRICAL/CELLULAR COMM.	+	+	E	E	+	+	+	E	E	+	+	+
ANTENNA SUPPORTS	+	+	E	–	+	+	+	E	E	+	E	E
CROSS ARMS	+	+	+	E	+	+	+	E	E	+	+	+
EMI/RFI ENCLOSURES	+	+	E	E	+	+	+	E	E	+	+	+
EQUIPMENT SCREEN WALLS/FASCIA	+	+	E	E	+	+	+	E	E	+	+	+
SPILL CONTAINMENTS	+	+	E	–	E	+	+	+	+	+	E	E
TRENCH COVERS	+	+	E	E	+	+	+	E	E	+	E	E
TRANSMISSION POLES	+	+	E	–	+	+	+	+	E	+	+	+
MARINE/OFF-SHORE	+	+	E	E	+	+	+	E	E	+	+	+
ACCESS WALKWAY SYSTEMS	+	+	E	E	+	+	+	E	E	+	+	+
DECK SYSTEMS	+	+	E	E	+	+	+	E	E	+	+	+
ENCLOSURES (EQUIPMENT/PERSONNEL)	+	+	E	E	+	+	+	E	E	+	+	+
EQUIPMENT SCREEN WALLS/FASCIA	+	+	E	E	+	+	+	E	E	+	+	+
MARINE LIFE AQUARIUM STRUCTURE	+	+	E	–	+	+	+	E	E	+	+	+
COMMERCIAL/ARCHITECTURAL	+	+	E	E	+	+	+	E	E	+	+	+
EXTERIOR RAIL/BALCONY SYSTEMS	+	+	E	E	+	+	+	+	E	+	+	+
FASCIA SYSTEMS	+	+	E	E	+	+	+	E	E	+	+	+
PENTHOUSE EQUIPMENT ENCLOSURES	+	+	E	E	+	+	+	E	E	+	+	+
ADA COMPLIANT DECKING SYSTEMS	+	+	E	E	+	+	+	E	E	+	E	E
POOL FENCING/RAILING	+	+	E	E	+	+	+	E	E	+	+	+
LIGHTING POLES	+	+	E	–	+	+	+	E	E	+	+	+
TRANSPORTATION/INFRASTRUCT.	+	+	E	E	+	+	+	E	E	+	E	E
CONCRETE REINFORCEMENTS	+	+	E	E	E	+	+	E	E	+	E	E
BRIDGE DECKS/SIDEWALKS	+	+	E	E	E	+	+	+	E	+	E	E
BRIDGE STRUCTURE	+	+	E	–	E	+	+	E	E	+	E	E
UTILITY COVERS	+	+	E	E	+	+	+	E	E	+	E	E
PARKS/RECREATION	+	+	E	E	+	+	+	E	E	+	E	E
PEDESTRIAN BRIDGE SYSTEMS	+	+	E	–	E	+	+	+	E	+	E	E
POOL GRATINGS/COVERS	+	+	E	E	+	+	+	E	E	+	E	E
UTILITY COVERS	+	+	E	E	+	+	+	E	E	+	E	E

superior in design and performance, and in the last decade, most have received FRP pultruded products not as a value engineered substitute for conventional materials, but as a targeted, first choice, specified material. *Figure 1 (page 23)* illustrates recently designed, fabricated and constructed facility that incorporates FRP pultruded structural shapes and building panels.

FRP Pultruded Products Codes and Standards

For over forty years structural engineers have relied upon design guides and manuals produced by manufacturers of the FRP pultruded products. These guides and manuals have served designers well; however, as with all mature construction materials, FRP must be incorporated into and governed by building codes and design standards. The 2009 *International Building Code*, produced by the International Code Council, contains new sections addressing the requirements and use of Fiber Reinforced Polymers and Fiberglass Reinforced Polymers in and on buildings and other structures. The American Society of Civil Engineers (ASCE) has been awarded a contract by an industry trade group, the American Composites Manufacturers Association (ACMA) to develop a pre-standard for *Load Resistance Factor Design (LRFD) Standard for Pultruded Fiber Reinforced Polymer (FRP) Structures*, and to carry the pre-standard through the ASCE standard balloting process. Once the Standard is completed and approved, it will be available to engineers through ASCE.

Key:

\+ *Out performs conventional materials typically used in this application*

E *FRP comparable to performance of conventional materials typically used in this application*

– *FRP has special property characteristics that may govern use in this application; other serviceability limit states that may govern use in these applications:*
- *Short-term deflection*
- *Vibrations from Dynamic Equipment*
- *High temperature (+150°F)*

[1] *Conventional Materials include structural steel, stainless steel, aluminum, concrete and timber construction.*

Conclusion

FRP pultruded structural shapes, plates, and building products have been used successfully worldwide for over forty years. These materials, and structures utilizing these materials, are now considered proven by engineers, constructors, and code officials. As the codes and standards bring these materials to the next level of recognition, structural engineers will continue to become increasingly familiar with the design, characteristics and benefits of pultruded structural FRP.▪

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