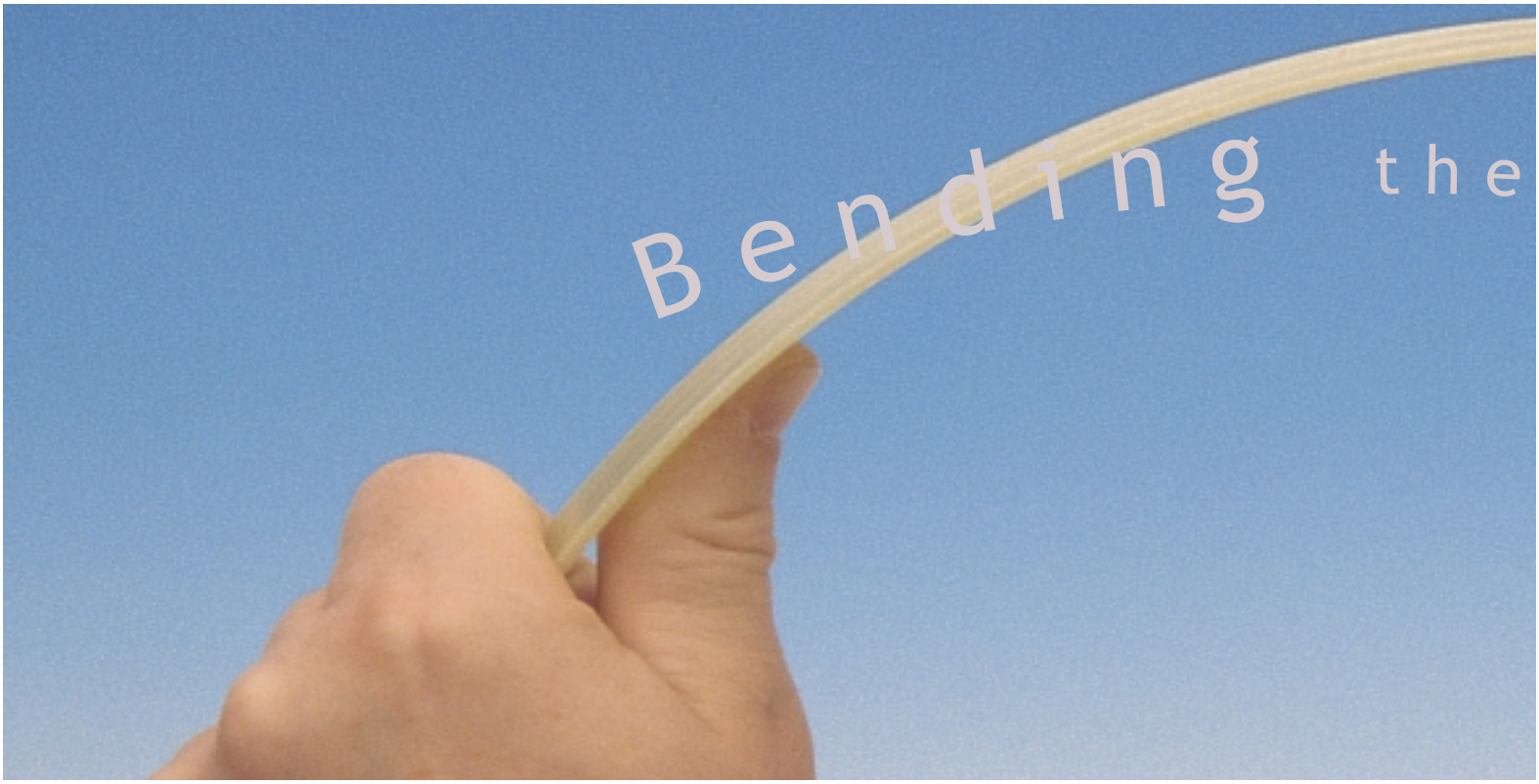
FULCRUM

Thermoplastic
Composite
Technology

FULCRUM™
Thermoplastic Composite Technology



"Impossible," They Said.

It's the combination of materials, properties, and performance that plastics manufacturers and suppliers have been trying to perfect for years: the high strength and stiffness of continuous-fiber reinforcement, combined with the advantages of a thermoplastic matrix.

Long thought impossible (or at the very least extremely impractical due to processing constraints), such a composite is now very real, very practical, and very applicable to a wide range of markets through FULCRUM* Thermoplastic Composite Technology.

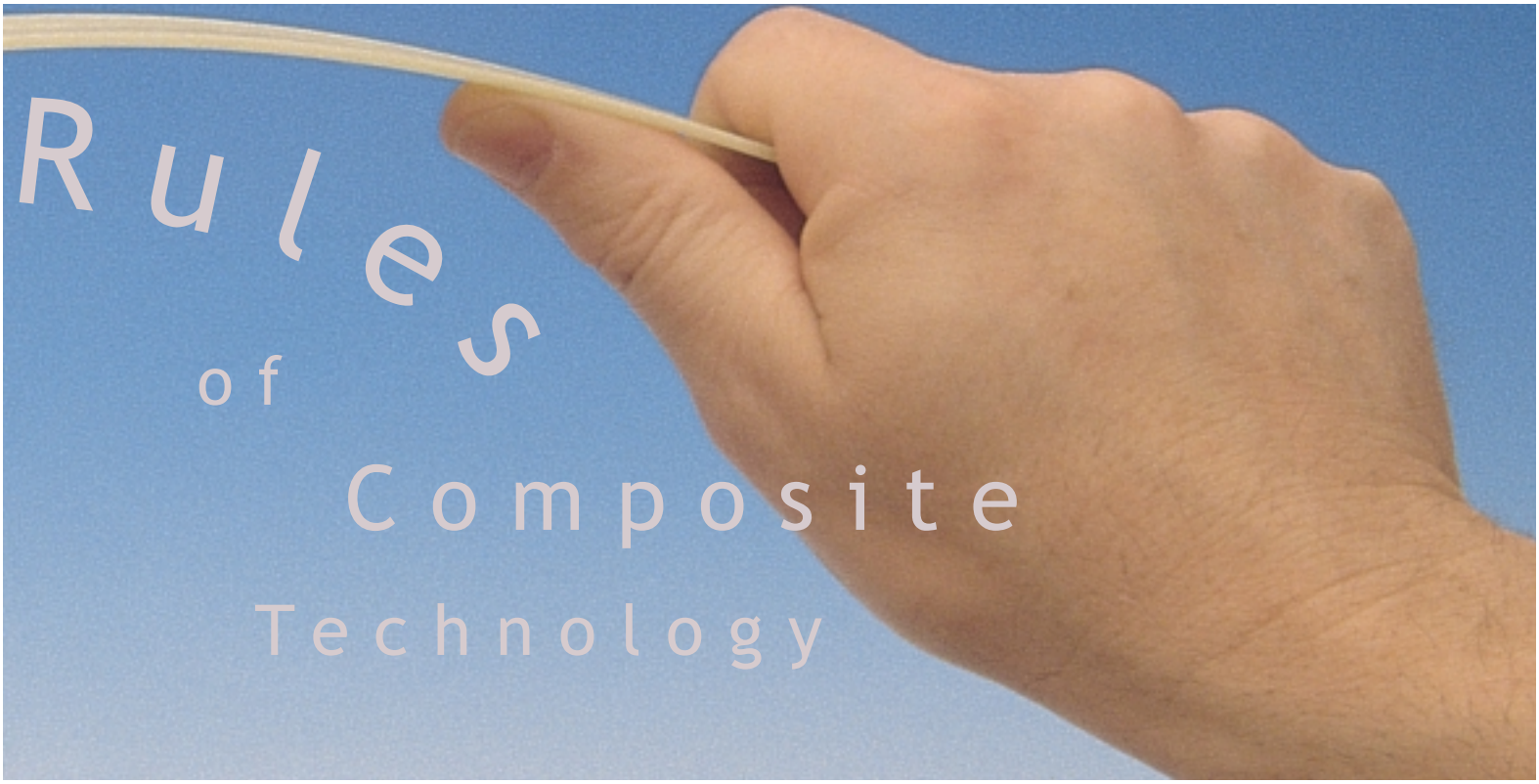
We Bent the Rules.

Traditionally, thermoplastic resins need high molecular weights (Mw) to achieve their properties. As a result, they have extremely high viscosities throughout the process and consequently require very high temperatures, pressures, and shear forces within the barrel of a compounding extruder in order to achieve significant contact with the glass fibers. Getting the viscosity of typical thermoplastics to a level at which significant wet-out can be achieved in continuous-fiber composites required reducing the Mw to a level at which the matrix properties are no longer interesting. Until now.

Using an engineering thermoplastic polyurethane (ETPU) matrix developed by The Dow Chemical Company, the rules of thermoplastic composites have changed with FULCRUM Thermoplastic Composite Technology. The ETPU resin has a unique chemistry which allows a reversal of the polymerization process in the melt phase, followed by a very rapid rebuild of molecular weight as the resin cools. This means the resin can be processed at extremely low viscosities while it retains very high molecular weight, providing excellent matrix properties in the final composite.

FULCRUM™
Thermoplastic Composite Technology

*Trademark of FULCRUM Composites Inc.



The Mechanical Properties of a Thermoset Composite in a Thermoplastic Matrix

FULCRUM Thermoplastic Composite Technology is a combination of a hardware and resin system design. The technology enables the production of high-performance composites based on a thermoplastic matrix with continuous-fiber reinforcement. Further, dies and processing equipment have been developed to take full advantage of the unique rheological behavior of an ETPU resin for the production of continuous-fiber composites via pultrusion.

Using the equipment and resin combination offered as part of FULCRUM Thermoplastic Composite Technology, it is now possible to produce thermoplastic composites not only with the very high mechanical properties characteristic of thermoset composites, but also with a wide range of additional advantages.

The Advantages of FULCRUM Thermoplastic Composite Technology

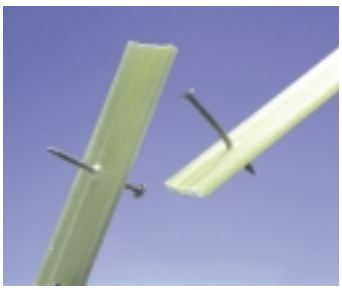
Strength and Stiffness – Fiber loadings as high as 70 percent by weight (60 volume) have been achieved, demonstrating mechanical properties at least equivalent to high-performance thermoset composites. Table 1 provides typical mechanical properties representative of thermoplastic composites made using FULCRUM Technology.

Table 1 Typical Mechanical Properties of Thermoplastic Composites Using FULCRUM Technology[1]

	Typical properties at 50 volume % glass
Tensile strength [MPa] [psi x 10^3]	1000 145
Tensile modulas [GPa] [psi x 10^3]	42 6.1
Longitudinal flexural strength [MPa] [psi x 10^3]	1200 175
Longitudinal flexural modulus [GPa] [psi x 10^6]	39 5.7
Transverse flexural strength [MPa] [psi x 10^6]	136 19.8
Compressive strength [MPa] [psi x 10^3]	450 65.3
Compressive modulus [GPa] [psi x 10^6]	36 5.2

[1] Typical property values, not to be used for design.

Toughness and Damage Tolerance - Thermoplastics in general are much tougher, more impact resistant, and have far higher elongation to failure than thermosets. FULCRUM Thermoplastic Composite Technology proves that this also leads to tougher and more damage-resistant continuous-fiber composites (see Figure 1). Typical elongation to break

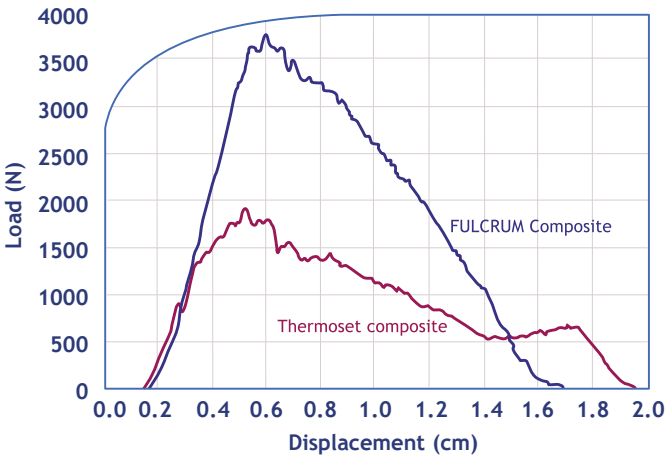


for thermoplastic composites made using FULCRUM Technology is approximately 2.5 percent, with an Izod impact higher than 5500 J/m (100 ft-lb/in).

High Productivity - FULCRUM Thermoplastic Composite Technology makes it possible to pultrude the new thermoplastic composites at very high rates, allowing higher productivity and greatly reduced capital and infrastructure investment. In fact, line speeds up to 5x that of thermoset composites have been achieved.

Load - Displacement Curves for High Speed Impact

Figure 1



Design Freedom - Although thermosets are amenable to many processing techniques, each is a one-time operation. Once the reaction is complete, no further change of shape or form is possible. With thermoplastic composites made with FULCRUM Technology, it is possible to weld, over-mold, and thermoform to create more complex 3-D shapes.

FULCRUM Composites can be easily formed with simple tooling.

FULCRUM Composites can also be over-extruded and co-extruded in-line.

Environmental Advantages - Unlike thermoset processes, the manufacture of thermoplastic composites does not result in emissions of volatile organic compounds (VOCs), making FULCRUM Thermoplastic Composite Technology ideal for today's environmentally conscious marketplace.

The thermoplastic composites are also recyclable; but even beyond that, the recyclate is valuable, having properties comparable to existing glass-filled engineering thermoplastics (see Table 2).

Structural Alternatives - As shown in Figure 2, thermoplastic composites offer manufacturers weight and cost advantages over many traditional materials. They offer the design processing freedom, density, and durability of thermoplastics combined with physical properties more normally associated with metals.

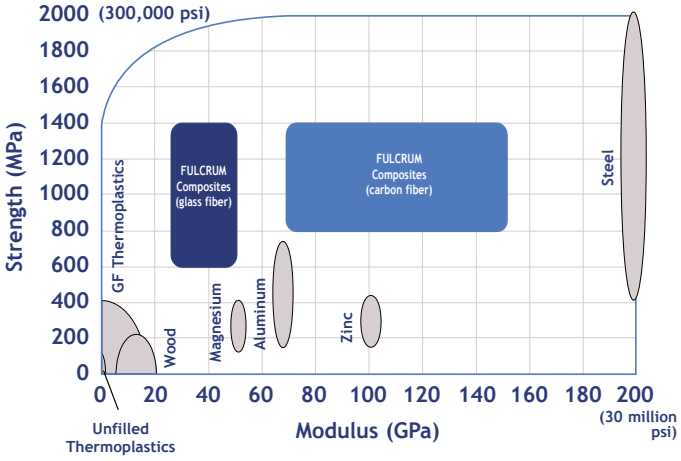
In addition to the headline properties of strength and stiffness, FULCRUM Composites can offer other structural advantages, for example, in improved off-axis properties. Whereas pultruded thermoset tube requires off-axis reinforcement to prevent premature failure from splitting, FULCRUM Composite tube with the same dimensions and no off-axis fibers has been demonstrated to be both stronger and stiffer.

Table 2 Mechanical Properties of Reground Composite Strip[1]

	Recycled Composite from FULCRUM Technology (Blended to 40% glass)	33% Virgin SGF PA 6,6[2] (Dry as molded)	33% Virgin SGF PA 6,6[2] (Conditioned)
Tensile strength [MPa] [psi]	142 20,600	190 27,600	140 20,300
Elongation at break [%]	2.4	2.0	3.7
E modulus [GPa] [psi x 10^3]	10.0 1450	9.5 1380	7.5 1090
Flexural strength [MPa] [psi]	223 32,300	276 40,000	200 29,000
Flexural modulus [GPa] [psi x 10^3]	11.0 1600	10.0 1450	5.5 800
Izod notch impact [J/m] [ft-lb/in]	216 4.0	86 1.6	162 3.0

[1] Typical property values, not to be used for design.
[2] Nylon 6,6 data are highest values quoted in Modern Plastics Encyclopedia 1998.

Figure 2 Comparison of Physical Properties Ranges of Structural Materials



Potential As Strong As the Composite Itself

The potential for FULCRUM Thermoplastic Composite Technology is obvious, and these thermoplastic composites are already establishing their own range of uses and applications in areas where they offer significant advantages over traditional materials and manufacturing techniques.

- Sports equipment
- Agriculture
- Infrastructure
- Industrial equipment
- Transportation
- Reinforcement of extrusions, injection moldings, and compression moldings

Table 3 provides a comparison of various structural materials and demonstrates the advantages of thermoplastic composites. With such obvious advantages, the use of thermoplastic composites can easily be considered for numerous markets and applications.

Materials Comparison

Table 3

	FULCRUM Thermoplastic Composites	Thermoset Composites	Steel	Aluminum	Wood	Thermo-plastics
Strength	+++	+++	+++	++	+	+
Strength to weight	+++	+++	-	+	+++	++
Recyclability	+++	-	+++	+++	++	+++
Corrosion Resistance	+++	+++	+	++	+	+++
Stiffness	++	++	+++	++	+	+
Formability	+++	-	+++	+++	+	+++

Explore Your Options.

Whatever your interests or requirements, we have the capability to assist you:

Supply Composite Profiles - We can supply a wide range of finished or semi-finished profiles to original equipment manufacturers (OEMs) and end users. These include a range of existing shapes, as well as the capability to design, manufacture, and supply new profiles tailored to your specific needs. Profiles may be hollow or solid, with decorative or functional cap layers and may be formed or shaped to your requirements.

License Manufacturing Technology - A number of processors have already licensed FULCRUM Technology for the commercial manufacture of thermoplastic composite profiles. These include thermoset pultruders, thermoplastic extruders, and OEMs. Our license package includes access to our broad patent portfolio, assistance in the design and start-up of your lines, ongoing assistance in die and profile development, and continued cooperation in the development of markets and applications.

Design, Development, and Structural Analysis - Recognizing the complexity of designing and using composites, we offer design and development capabilities for the creation and use of FULCRUM Composite profiles. This may range from simple discussions on feasibility and material selection for a new concept to in-depth development of a new product or process. We offer full CAD and Finite Element Structural Analysis service for both FULCRUM Composites and other materials.

Please contact us with your requirements:

Phone 989-636-1025

eMail info@fulcrumcomposites.com

Or visit us on the web at:
www.fulcrumcomposites.com

Our History.

FULCRUM Thermoplastic Composite Technology was developed and commercialized by The Dow Chemical Company. In March 2004, FULCRUM Composites Inc. was formed to carry on the technical and commercial evolution of FULCRUM Technology. FULCRUM Composites and The Dow Chemical Company continue to have a close relationship for the supply of resins used in the manufacture of FULCRUM Composites.

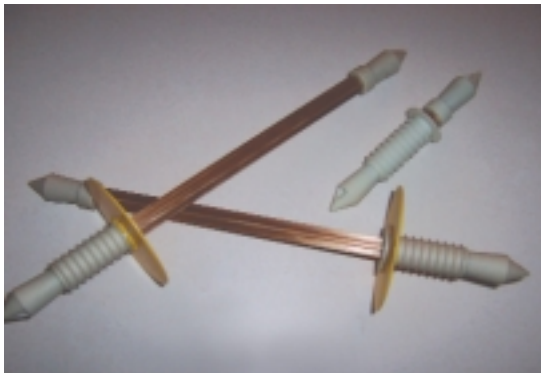
FULCRUM™
Thermoplastic Composite Technology

Typical applications of FULCRUM* Thermoplastic Composites:

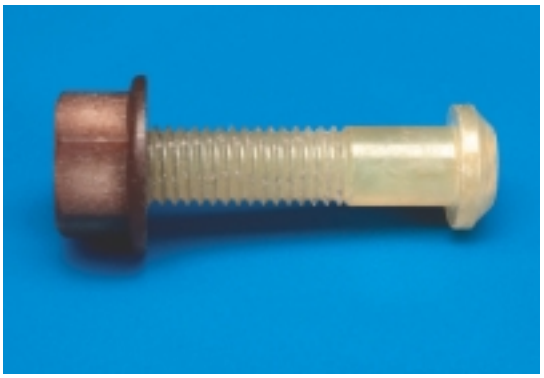
Ladder rail

Ski poles (courtesy Topglass SpA)

FULCRUM Composite profiles for various structural applications



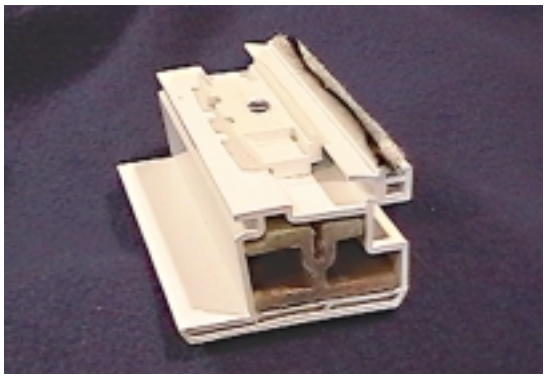
Concrete panel connectors (courtesy Thermomass Building Systems and Topglass SpA)



Thermoformed bolt (courtesy Click Bond)

Formable composite reebar

Structural reinforcement (courtesy Rotofix UK and Topglass SpA)



Window profile stiffener (courtesy Milgard Windows)