STRONGWELL

INTRODUCTION TO EXTREN®

WHAT IS EXTREN®

EXTREN® is the registered trade name for a proprietary line of standard pultruded fiberglass structural shapes and plate produced by Strongwell. The EXTREN® line consists of more than 100 different fiberglass shapes, each with a very specific, proprietary composite design.

Types of glass reinforcements used in EXTREN®

Continuous filament mat:	Long glass fibers intertwined and bound with a small amount of resin called a binder. The mat provides multi-directional strength properties.
Continuous strand roving:	Each strand contains 800-4,000 fiber filaments. Many strands are used in each pultruded profile. The rovings provide strength in the longitudinal (pultruded) direction.
Multiaxial reinforcements:	High-performance, engineered fabrics consisting of unidirectional fibers oriented in one or more directions.
Other:	Other reinforcements may be used based on performance requirements.

Resins used in EXTREN®

Polyester:	A general duty resin which provides excellent corrosion resistance in many applications.
Vinyl Ester:	A premium grade resin which has higher strength properties, retains strength better at elevated temperatures, and provides a wider range of corrosion resistance than polyester.
Custom:	EXTREN® Series 900 may use custom resin systems or blends.

Surfacing Veil

All EXTREN® has a surfacing veil of polyester non-woven fabric which encases the glass reinforcement and adds a resin-rich surface. This combination of fabric and resin provides greater protection against corrosives and also eliminates "fiber blooming" (the occurrence of glass fibers on the surface) which was prevalent in early pultruded shapes in outdoor applications.

THE FEATURES OF EXTREN®

EXTREN® structural shapes have numerous features that engineers might use individually or in combination to solve structural problems.

- **HIGH STRENGTH** - Stronger than structural steel on a pound-for-pound basis (in the 0° direction), EXTREN® has been used to form the superstructures of multistory buildings, walkways, sub-floors, and platforms.
- **LIGHTWEIGHT** - Weighing as much as 80% less than steel and 30% less than aluminum, EXTREN® structural shapes are easily transported, handled, and lifted into place. Total structures can often be preassembled and shipped to the jobsite ready for installation.
- **CORROSION RESISTANT** - EXTREN® will not rot and is impervious to a broad range of corrosive environments. This feature makes it a natural selection for indoor or outdoor structures in pulp and paper mills, chemical plants, water and sewage treatment plants, or other corrosive environments.
- **LOW CONDUCTIVITY** - An excellent insulator, EXTREN® has low electrical and thermal conductivity.

- **ELECTRO-MAGNETIC TRANSPARENCY** - EXTREN® is transparent to radio waves, microwaves, and other electromagnetic frequencies.
- **DIMENSIONAL STABILITY** - The coefficient of thermal expansion of EXTREN® shapes is slightly less than steel in the 0° direction and significantly less than aluminum.

THE EXTREN® SERIES

EXTREN® is pultruded structural composite profiles and plate produced exclusively by Strongwell with the EXTREN® logo embedded in the surfacing veil. It meets or exceeds the minimum published mechanical, physical, electrical, flammability, and corrosive properties of the respective Series published in the *Strongwell Design Manual*.

EXTREN® SERIES 500

Premium Polyester Resin, UV inhibitor added, standard color is olive green.

A general purpose resin with excellent corrosion properties

EXTREN® SERIES 525

Premium Polyester Resin, Flame retardant additives, UV inhibitor added, standard color is slate gray.

A general purpose resin with excellent corrosion properties and improved fire performance

EXTREN® SERIES 600

Premium Vinyl Ester Resin, UV inhibitor added, standard color is light gray.

For harsher corrosive environments and higher temperature applications

EXTREN® SERIES 625

Premium Vinyl Ester Resin, Flame retardant additives, UV inhibitor added, standard color is beige.

For harsher corrosive environments, higher temperature applications, with improved fire performance

EXTREN® SERIES 900

In addition to EXTREN® products, Strongwell manufactures custom pultrusions. These pultrusions vary from EXTREN® in either shape, resin type, or reinforcement (type, amount, location and/or orientation). Designers may choose to vary one or all of these parameters to improve strength, temperature resistance, corrosion resistance, machinability or some other characteristic. See Design Manual Section 18 - CUSTOM PULTRUSIONS. Consult Strongwell with specific needs or questions.

EXTREN DWB® is pultruded structural composite double web beam with surfacing veil produced exclusively by Strongwell. It meets or exceeds the minimum published mechanical and physical properties of EXTREN DWB® published in the *Strongwell Design Manual*. See Design Manual Section 17 - EXTREN DWB® DESIGN GUIDE.

EXTREN TC® is pultruded structural composite thermal cure rod and bar produced exclusively by Strongwell. It does not contain a surfacing veil or logo unless requested. EXTREN TC® meets or exceeds the minimum published mechanical, physical, electrical, flammability, and corrosive properties of EXTREN TC® published in the *Strongwell Design Manual*.

E23

All standard EXTREN® products meet and/or exceed the structural requirements of E17 European standards. EXTREN® can be manufactured upon request to meet the mechanical and physical properties of BS EN 13706 (E23) European standards.

NSF International

Most Strongwell products can be manufactured to meet NSF-61 certification upon request. Contact Strongwell for details.

EXTREN® VS. CONVENTIONAL MATERIALS

Designing with EXTREN® using the Strongwell Design Manual is not much different than designing with other materials. The designer should, however, keep the following primary differences in mind:

Relatively Low Modulus of Elasticity

The modulus of elasticity of EXTREN® is approximately one-tenth that of steel. As a result, deflection is often a controlling design factor.

Anisotropic

Pultruded composites are not homogeneous or isotropic; therefore, the mechanical properties of EXTREN® are directional. When designing with EXTREN®, it is important to consider stresses in both the transverse and longitudinal directions.

Relatively Low In-Plane Shear Modulus

The shear modulus of pultruded fiberglass shapes is low compared to metals. Accordingly, the designer should be aware that shear stresses add deflection to loaded beams above the classical flexural deflection. Refer to Design Manual Section 8 - FLEXURAL MEMBERS for more detailed information and design examples.

The Effect of Temperature

EXTREN® structural shapes are more susceptible to property degradation at high temperatures than are metals. The designer should keep this in mind where the design temperature is above 150°F for polyester and 200°F for vinyl ester. Contrary to intuitive thinking, EXTREN® shapes become stiffer in cold temperatures. See "Temperature Effects" in Design Manual Section 3 - PROPERTIES OF EXTREN® for expanded discussion of the effects of temperature.

Corrosion Resistance

EXTREN® shapes are often placed in corrosive environments. Generally, EXTREN® shapes offer superior corrosion resistance when compared to conventional building materials. See Design Manual Section 22 - CORROSION RESISTANCE GUIDE for guidance.

EXTREN® Structural Tube Is Not Pipe

EXTREN® tubes have been designed for structural applications such as columns and handrails and not as fluid carrying pipe. EXTREN® may be used to carry fluids if there is no internal pressure. The end-user should consult Design Manual Section 22 - CORROSION RESISTANCE GUIDE to confirm the suitability of the resin to handle the fluid being considered and should also test the EXTREN® tube to confirm its ability to carry the fluid without leaking.

EXTREN® VS. OTHER PULTRUDED PRODUCTS

The designer should be aware that two pultruded shapes with identical external dimensions can vary dramatically in physical properties depending on the resin formulation and the amount and type of reinforcement. The Strongwell Design Manual should not be used for fiberglass shapes other than those manufactured by Strongwell.

PROPERTIES OF EXTREN®

INTRODUCTION

The properties in this section are for product as produced by Strongwell and the data sheets in this section present the minimum ultimate values from testing in conformance to ASTM procedures. These values are obtained from coupons machined from EXTREN® structural shapes and function as a proof test for the EXTREN® composite. Descriptions of the ASTM test procedures are found at the end of this section.

Strongwell verifies the full section bending Modulus of Elasticity using a simple beam concept at the start of each production run. The empirically determined EXTREN® structural design equations presented in later sections will be a function of the Modulus of Elasticity.

The designer must consider environmental factors in designing for the actual application. These factors include elevated temperature and corrosive chemicals.

TEMPERATURE EFFECTS

The approximate retention of mechanical properties at elevated temperatures are:

		EXTREN® Series 500/525	**EXTREN® Series 600/625**
Ultimate Strength	100°F	85%	90%
	125°F	70%	85%
	150°F	50%	80%
	175°F	not recommended	75%
	200°F	not recommended	50%
	>200°F	not recommended	not recommended
Modulus of Elasticity	100°F	100%	100%
	125°F	90%	95%
	150°F	85%	90%
	175°F	not recommended	88%
	200°F	not recommended	85%
	>200°F	not recommended	not recommended

These recommendations are based on the normal EXTREN® proprietary resin system. Strongwell routinely processes other resin systems to achieve higher temperature ratings for specific applications. Independent test data confirms that EXTREN® structural shapes and plate maintain their mechanical and physical properties for temperatures down to at least -60°F.

CORROSION EFFECTS

As a general rule, the polyester resin used in EXTREN® Series 500/525 is resistant to most acidic attacks while the vinyl ester resin in EXTREN® Series 600/625 is resistant to acids and bases. The effect of corrosive chemicals is temperature dependent with elevated temperature increasing the corrosion activity. A corrosion guide is available in the *Strongwell Design Manual* and a Strongwell salesperson can respond to chemicals not listed in this guide.

Strongwell incorporates a synthetic veil on the surface of all EXTREN® structural shapes which causes a resin-rich layer, enhancing corrosion protection.

UV (ULTRAVIOLET RADIATION) EFFECTS

UV is a sunlight-produced environmental attack on FRP composites. The synthetic surfacing veil also aids in protecting the composite from UV degradation, the effect of which is sometimes referred to as “fiber blooming”. EXTREN® also contains a UV inhibitor.

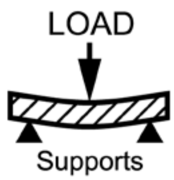
There is a large variation in the degree of fading from UV degradation based on the color selected. It should be noted that the surfacing veil, while not preventing color fading, serves to protect the composite from any mechanical property degradation potentially caused by UV. Coating with materials such as UV stabilized polyurethane based paints are very effective in maintaining the color and offer the optimum long-term protection from UV attack.

DESCRIPTION OF TESTS FOR EXTREN®

TENSILE STRENGTH (ASTM D638)

The tensile strength is determined by pulling ends of a test specimen until failure. The tensile modulus can be calculated by measuring the ratio of stress and strain. When the tensile strength is measured in the longitudinal direction, as a first approximation, it is an indication of relative roving content. For example, an all roving thermal cure rod has a higher tensile strength than the EXTREN® structural shapes which are a combination of roving and continuous strand mat.

FLEXURAL PROPERTIES (ASTM D790)

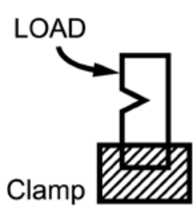


The flexural strength is determined by placing a test specimen between two supports and applying a load to the center. ASTM D790 specifies required span to depth ratios for the test specimen. Flexural tests on coupon samples are often used to determine the effects of environmental conditions such as temperature and corrosive agents.

COMPRESSIVE STRENGTH (ASTM D695)

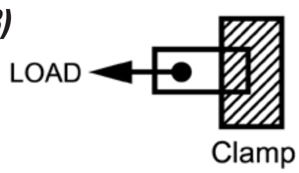
The ultimate compressive strength of a composite is a force required to rupture the composite when a load is applied such that the specimen is crushed. The compressive test is an excellent indication of the resin matrix to reinforcement bond and has been adopted by the ANSI A14.5 specification for fiberglass rail as the primary physical property audit.

IZOD IMPACT (ASTM D256)



The Izod impact is determined by subjecting a specimen to a pendulum-type collision; the specimen can be notched or unnotched. The energy required to rupture the specimen due to the collision caused by the swinging pendulum is used to calculate the Izod impact strength.

BEARING STRESS (ASTM D953)



This test specimen consists of a flat strip with a hole machined in one end as specified by the ASTM procedure. The testing consists of clamping the end without the hole and attempting to tear or rupture the hole in the specimen. The load required to rupture the hole is used to determine the bearing stress.

MODULUS OF ELASTICITY

This parameter is determined by loading a prescribed length of the full shape (not a coupon) with a support at each end and applying a center load. From the measured deflection and the known load and span, the bending modulus of elasticity can be determined once the shear deflection effects are identified. This is a more reliable estimate of the field performance in beam bending situation than the coupon properties.

BARCOL HARDNESS (ASTM D2583)

The barcol hardness is a measure of the resistance of the surface of a test specimen to penetration by a needle probe which is spring driven. The barcol hardness value is generally an average of multiple measurements on the same part and is an approximate measure of the composite's completeness of cure.

WATER ABSORPTION (ASTM D570)

In this test, the specimens are immersed in water for a period of 24 hours and the change in weight is measured. This test has utility in electrical and corrosive applications.

DENSITY (ASTM D792)

The density is the ratio of the mass (weight) of a specimen to the volume of the specimen. This parameter is important in determining the ultimate weight of the finished product.

SPECIFIC GRAVITY (ASTM D792)

The ratio of the density of a composite to the density of water.

ARC RESISTANCE (ASTM D495)

This test is performed by placing two probes on a test specimen at a distance of 1/4". A high voltage, low current arc is passed between the probes with a specified on/off cycle for this arc. The time taken for the arc to completely burn a path through the composite is measured.

DIELECTRIC STRENGTH (ASTM D149)

In this electrical test, the sample is placed between electrodes with the electrodes and the sample immersed in non-conducting oil to prevent a false failure signal. Failure occurs when the voltage is sufficient to cause the current to discharge through the composite. This test is occasionally performed after conditioning the test specimen with water at elevated temperatures.

WEATHERING QUV WEATHEROMETER (ASTM G53)

The QUV Weatherometer applies alternating cycles of water, high temperature, humidity and ultraviolet exposure to measure the weatherability of a given composite and/or additive. This test is primarily comparative in nature between composites and/or formulations. The geographic location of the composite will determine its actual weatherability.

UL 94

EXTREN® Series 525 and Series 625 conform to UL 94 testing with a V-0 Rating. In the UL 94 test, a vertically clamped sample is subjected to a flame from a Bunsen burner.

TUNNEL TEST (ASTM E84)

In the 25 foot tunnel test, a smoke generation value and the rate of flame spread are determined. This test has been the standard for years in measuring flammability and smoke generation.

NBS SMOKE CHAMBER (ASTM E662)

This test requires a much smaller test specimen and essentially places this specimen in the bottom of a chamber and measures the smoke that is generated to an optical detector at the top of the chamber.

FLAMMABILITY (ASTM D635)

This is a less severe flammability test in which the specimen is held horizontally with one end subjected to a flame for 30 seconds.

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EXTREN® vs. TRADITIONAL MATERIALS (PROPERTY COMPARISON)

MECHANICAL		EXTREN® 500/525 SHAPES	EXTREN® 600/625 SHAPES	EXTREN TC® ROD AND BAR	CARBON STEEL (M1020)	316 STAINLESS STEEL	HASTELLOY C-276 (ANNLD.)	ALUMINUM 6061-T61 T651	PONDEROSA PINE	RIGID PVC	RIGID PVC 10% GLASS	FIBERGLASS COMPRESSION MOLDING (SMC)	SPRAY-UP (30-50% GLASS)
Tensile Strength ($x 10^3$ psi) (Yield)	LW	30	30	100	60	80	100	45	0.42	6.2	7.8	8 - 20	9 - 18
	CW	7	7	—	60	80	100	45	—	6.2	7.8	8 - 20	9 - 18
Tensile Modulus ($x 10^6$ psi)	LW	2.5	2.6	6	30	28	26	10	—	0.39	0.47	1.6 - 2.5	0.8 - 1.8
	CW	0.8	0.8	—	30	28	26	10	—	0.39	0.47	1.6 - 2.5	0.8 - 1.8
Flexural Strength ($x 10^3$ psi)	LW	30	30	100	60	80	100	45	15.4	11	11.7	18 - 30	16 - 28
	CW	10	10	—	60	80	—	45	9.4	11	11.7	18 - 30	16 - 28
Flexural Modulus ($x 10^6$ psi)	LW	1.6	1.6	6	30	28	26	10	1	0.35	0.45	1.3 - 1.8	1 - 1.2
	CW	0.8	0.8	—	30	28	26	10	—	0.35	0.45	1.3 - 1.8	1 - 1.2
Izod Impact (ft-lb/in)	LW	25	25	40	N/A	8.5 - 11	—	—	—	1.6	1.6	10 - 20	4 - 12
	CW	4	4	—	N/A	—	—	—	—	1.6	1.6	10 - 20	4 - 12
Specific Gravity		1.7	1.7	2	7.8	7.92	8.96	2.5	0.52	1.38	1.39	1.5 - 1.7	1.4 - 1.6
PHYSICAL													
Density (lbs/in^3)		0.062 - 0.070	0.062 - 0.070	0.072 - 0.076	0.284	0.29	0.324	0.092	0.019	0.052	0.052	0.054 - 0.061	0.05 - 0.059
Thermal Conductivity (BTU/SF/HR/°F/in)		4	4	5	260 - 460	96 - 185	71	1200	0.08	1.3	—	1.3 - 1.7	1.2 - 1.6
Coefficient of Thermal Expansion (10^{-6} in/in/°F)		7	7	5	6 - 8	9 - 10		13.5	1.7	37	23	10 - 18	12 - 20

FIBERGLASS PULTRUSION THICKNESS RELATIVE TO STEEL, ALUMINUM, OR WOOD①

FIBERGLASS PULTRUSION CONSTRUCTION	STEEL*			ALUMINUM*			WOOD*		
	TENSILE STRENGTH	RIGIDITY	FLEXURAL STRENGTH	TENSILE STRENGTH	RIGIDITY	FLEXURAL STRENGTH	TENSILE STRENGTH	RIGIDITY	FLEXURAL STRENGTH
50% Mat & Roving (EXTREN®)	2.5	2.15	1.82	1.0	1.49	1.16	0.25	0.79	0.45
70% Roving Only (Thermal Cure Rod & Bar)	1.0	1.71	1.12	0.4	1.19	0.71	0.10	0.63	0.27

**Copied from Engineered Materials Handbook, Vol. 1, "Composites," pg. 541.*

①*As an example, a 50% mat & roving fiberglass pultrusion would need to be 1.16 times as thick as an aluminum part to achieve the same "flexural strength".*

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EXTREN® vs. TRADITIONAL MATERIALS
(QUICK CHEMICAL RESISTANCE COMPARISON CHART)

R = RECOMMENDED
NR = NOT RECOMMENDED

	CHEMICAL ENVIRONMENT*												
	SULFURIC ACID		HYDROCHLORIC ACID		HYDRO-FLUORIC ACID	PHOSPHORIC ACID		SODIUM HYDROXIDE		ACID CHLORIDE SALTS	BLEACH	WET CHLORINE	NITRIC ACID
MATERIALS	DILUTE	CONCENTRATE	DILUTE	CONCENTRATE		DILUTE	CONCENTRATE	DILUTE	CONCENTRATE				
EXTREN® Series 500 & 525	R (Below 30%)	NR	R	R	NR	R	R	NR	NR	R	NR	NR	R (Below 5%)
EXTREN® Series 600 & 625	R	R (To 75%)	R	R	R	R	R	R	R	R	R	R	R
Carbon Steel (M1020)	NR	R (Above 85%)	NR	NR	NR	NR	NR	R	R	NR	NR	NR	NR
316 Stainless Steel	R (Below 5%)	R (Above 85%)	NR	NR	NR	R	R	R	NR	NR	NR	NR	R
Hastelloy C	R	R	R	R	R	R	R	R	R	R	R	R	R
Aluminum	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

**Assuming Room Temperature*

ST0720