INTRODUCTION TO EXTREN®

WHAT IS EXTREN®

EXTREN® is the registered trade name for a proprietary line of standard pultruded fiberglass structural shapes 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 strand 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.

Resins Used In EXTREN®

Isophthalic polyester:	A general duty resin which provides adequate 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.

Surfacing Veil

All EXTREN® shapes has a surfacing veil of polyester non-woven fabric which encases the glass reinforcement and adds a layer of resin to the surface. This combination of fabric and resin provides greater protection against ultraviolet degradation and corrosives. Surfacing veil also eliminates “fiber blooming” (the occurrence of glass fibers on the surface) which was prevalent in early stages 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, EXTREN® has been used to form the superstructures of multistory buildings, walkways, sub-floors and platforms.
- **LIGHTWEIGHT** — Weighing 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 job site 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.
- **NON-CONDUCTIVE** — An excellent insulator, EXTREN® has low thermal conductivity and is electrically non-conductive.
- **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 and significantly less than aluminum.

THE THREE EXTREN® SERIES

EXTREN® shapes are produced in three standard resin systems which comprise the three series of EXTREN®.

EXTREN® SERIES 500

Resin — Isophthalic Polyester

Standard Color — Olive Green

UV Inhibitor — Yes
(Note: Strongwell began using UV inhibitor in S-500 during the first quarter of 1997. Stocked items produced before this will not include the UV inhibitor.)

Purpose — General use

EXTREN® SERIES 525

Resin — Isophthalic Polyester with Flame Retardant Additive

Standard Color — Slate Gray

UV Inhibitor — Yes

Purpose — General use when flame retardancy is required

EXTREN® SERIES 625

Resin — Vinyl Ester with Flame Retardant Additive

Standard Color — Beige

UV Inhibitor — Yes

Purpose — Structures where the environment is highly corrosive

NOTE: In addition to EXTREN® products, Strongwell manufactures custom pultrusions. These pultrusions vary from EXTREN® in either shape, resin type, or reinforcement type, amount, location 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. Consult Strongwell with specific needs or questions.

EXTREN® VS. CONVENTIONAL MATERIALS

Designing with EXTREN® 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 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.

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. Contrary to intuitive thinking, EXTREN® shapes become stronger in cold temperatures.

Corrosion Resistance

EXTREN® shapes are often placed in corrosive environments. General EXTREN® shapes offer superior corrosion resistance when compared to conventional building materials.

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 not internal pressure. The end-user should consult the *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

Referring to the previous discussion of "What is Fiberglass Reinforced Plastic," 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. Accordingly, this manual should not be used for fiberglass shapes other than EXTREN®.

The key word in describing EXTREN® is "standard." EXTREN® is a product line of standard shapes with standard mechanical properties. If the pultruded product is not EXTREN®, we refer to it as a "custom pultrusion".

PROPERTIES OF EXTREN®

INTRODUCTION

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.

Strongwell verifies the full section bending Modulus of Elasticity using a simple beam concept at the start of each production run and periodically thereafter. The empirically determined EXTREN® structural design equations 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®	
	Temperature	**Series 500/525**	**Series 625**
Ultimate Stress	100° F	85%	90%
	125° F	70%	80%
	150° F	50%	80%
	175° F	not recommended	75%
	200° F	not recommended	50%
	100° F	100%	100%
	125° F	90%	95%
Modulus of Elasticity	150° F	85%	90%
	175° F	not recommended	88%
	200° F	not recommended	85%

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.

CORROSION EFFECTS

As a general rule, the isophthalic polyester resin used in EXTREN® Series 500/525 is resistant to most acidic attacks while the vinyl ester resin in EXTREN® Series 625 is resistant to acids and bases. The effect of corrosive chemicals is temperature dependent with elevated temperature increasing the corrosion activity.

Strongwell incorporates a synthetic veil on the surface of all EXTREN® structural shapes which causes a resin rich layer which enhances 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® Series 525 and Series 625 also contain a UV inhibitor to enhance the protection against sunlight.

There is a large variation in the degree of fading from UV degradation based on the color selected. While this fading is undesirable, the structural integrity of the composite will remain unaffected if the surfacing veil is utilized. 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 EXTREN® 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 un-notched. 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 procedures. 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.

COMPRESSIVE SHEAR STRENGTH (ASTM D3846)

In the shear test, a full thickness test specimen is notched on two sides of the test area such that the applied load is acting upon only a small cross section. The load can be either tensile or compressive and the notches can be oriented differently.

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 that 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)

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 are listed with a VO rating at UL. In the UL 94 test, a vertically clamped sample is subjected to a flame from a bunsen burner; the flame height is carefully controlled by UL specifications.

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® 625 SHAPES	THERMAL CURE 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 CW	30 ① 7 ①	30 ① 7 ①	100 ① —	35 35	30-35 30-35	50 50	45 45	42 —	6.2 —	7.8 —	8-20 —	9-18 —
Tensile Modulus ($x 10^6$ psi)	LW CW	2.5 .8	2.6 1	6 —	30 30	28 28	26 26	10 10	— —	.39 .39	.47 .47	1.6-2.5 1.6-2.5	.8-1.8 .8-1.8
Flexural Strength ($x 10^3$ psi)	LW CW	30 10	30 10	100 —	35 35	30-35 30-35	50 —	45 45	.725 9.4	11 11	11.7 11.7	18-30 —	16-28 —
Flexural Modulus ($x 10^6$ psi)	LW CW	2 .8	2.2 .8	6 —	30 30	28 28	26 26	10 10	1 —	.35 .35	.45 .45	1.3-1.8 —	1-1.2 —
Izod Impact (ft-lb/in)	LW CW	25 4	25 4	40 —	N/A N/A	8.5-11 —	— —	— —	— —	1.6 1.6	1.6 1.6	10-20 —	4-12 —
Specific Gravity		1.7	1.7	2	7.8	7.92	8.96	2.5	.52	1.38	1.39	1.5-1.7	1.4-1.6
PHYSICAL													
Density (lbs/in^3)		.062-.07	.062-.07	.072-.076	.284	.29	.324	.092	.019	.052	.052	.054-.061	.05-.059
Thermal Conductivity (BTU/SF/HR/°F/in)		4	4	5	260-460	96-185	71	1200	.08	1.3	—	1.3-1.7	1.2-1.6
Coefficient of Linear Expansion (10^{-6} in/in/°F)		5.2	5.2	3	6-8	9-10		13.5	1.7	37	23	10-18	12-20

① Minimum Ultimate Property From Coupons

"FIBERGLASS PULTRUSION THICKNESS" RELATIVE TO STEEL, ALUMINUM OR WOOD

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	.25	.79	.45
70% Roving Only (Thermal Cure Rod & Bar)	1.0	1.71	1.12	.4	1.19	.71	.10	.63	.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)

MATERIALS	CHEMICAL ENVIRONMENT*							R=RECOMMENDED			NR=NOT RECOMMENDED		
	Sulfuric Acid Dilute	Sulfuric Acid Concentrate	Hydrochloric Acid Dilute	Hydrochloric Acid Concentrate	Hydrofluric Acid	Phosphoric Aicd Dilute	Phosphoric Acid Concentrate	Sodium Hydroxide Dilute	Soduim Hydroxide Concentrate	Acid Chloride Salts	Bleach	Wet Chlorine	Nitric Acid
EXTREN® Series 500 & 525	R (Below 30%)	NR	R	R	NR	R	R	NR	NR	R	NR	NR	R (Below 5%)
EXTREN® Series 625	R	R (To 75%)	R	R	R	R	R	R	R	R	R	R	R
Carbon Steel (1020)	NR	R (Above 85%)	NR	NR	NR	NR	NR	R	R	NR	NR	NR	NR
316 Stainless	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