# SECTION 3

# PROPERTIES OF EXTREN®

Look for this blue line in the left margin of the Design Manual documents. This line shows you where the latest update has been made.

# PROPERTIES OF EXTREN®

## INTRODUCTION

The properties in this manual 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** | **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 isophthalic 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 has been included in this 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.

# SERIES 500/525/600/625 STRUCTURAL SHAPES
# ULTIMATE COUPON PROPERTIES

Below are the test results for the **minimum** ultimate **coupon** properties of **EXTREN®** structural shapes as per the referenced ASTM procedures. The properties of plate as well as thermal cure rod and bar are found elsewhere in this section. Designers should refer to Section 8 — **FLEXURAL MEMBERS** and Section 9 — **COMPRESSION MEMBERS** for the recommended design equations for **EXTREN®**. The actual geometry and application of the structural shape will determine its ultimate usability. Additionally, WF / I-Beam ASTM properties may vary due to location in the part but the modulus of elasticity will not be affected.

| PROPERTY | ASTM TEST | UNITS | SERIES 500/525 | SERIES 600/625 |
|---|---|---|---|---|
| **MECHANICAL** | | | | |
| Tensile Stress, LW | D638 | psi | 30,000 | 30,000 |
| Tensile Stress, CW | D638 | psi | 7,000 | 7,000 |
| Tensile Modulus, LW | D638 | $10^6$ psi | 2.5 | 2.6 |
| Tensile Modulus, CW | D638 | $10^6$ psi | 0.8 | 0.8 |
| Compressive Stress, LW① | D695 | psi | 30,000 | 30,000 |
| Compressive Stress, CW | D695 | psi | 15,000 | 16,000 |
| Compressive Modulus, LW | D695 | $10^6$ psi | 2.5 | 2.6 |
| Compressive Modulus CW | D695 | $10^6$ psi | 0.8 | 0.8 |
| Flexural Stress, LW② | D790 | psi | 30,000 | 30,000 |
| Flexural Stress, CW | D790 | psi | 10,000 | 10,000 |
| Flexural Modulus, LW② | D790 | $10^6$ psi | 1.6 | 1.6 |
| Flexural Modulus, CW | D790 | $10^6$ psi | 0.8 | 0.8 |
| Modulus of Elasticity ③ | Full Section | $10^6$ psi | 2.6 | 2.8 |
| Modulus of Elasticity (W and I Shapes > 4") ③ | Full Section | $10^6$ psi | 2.5 | 2.5 |
| Shear Modulus, LW ④⑧ | D5379 | $10^6$ psi | 0.425 | 0.425 |
| Short Beam Shear, LW ⑦⑧ | D2344 | psi | 4,500 | 4,500 |
| Ultimate Bearing Stress, LW | D953 | psi | 30,000 | 30,000 |
| Poisson's Ratio, LW⑧ | D3039 | in/in | 0.33 | 0.33 |
| Notched Izod Impact, LW | D256 | ft-lbs/in | 25 | 25 |
| Notched Izod Impact, CW | D256 | ft-lbs/in | 4 | 4 |
| **PHYSICAL** | | | | |
| Barcol Hardness⑤ | D2583 | — | 45 | 45 |
| 24 hr. Water Absorption⑥ | D570 | % Max | 0.60 | 0.60 |
| Density | D792 | lbs/in$^3$ | 0.062-0.070 | 0.062-0.070 |
| Coefficient of Thermal Expansion, LW ⑧ | D696 | $10^{-6}$ in/in/°F | 7 | 7 |
| Coefficient of Thermal Expansion, CW ⑧ | D696 | $10^{-6}$ in/in/°F | 16 | 16 |
| Thermal Conductivity ⑧ | C177 | BTU-in/ft$^2$/hr/°F | 4 | 4 |
| **ELECTRICAL** | | | | |
| Arc Resistance, LW ⑧ | D495 | seconds | 120 | 120 |
| Dielectric Strength, LW ⑧ | D149 | KV/in | 35 | 35 |
| Dielectric Strength, PF ⑨ | D149 | volts/mil | 200 | 200 |

| PROPERTY | TEST | VALUE |
|---|---|---|
| **FLAMMABILITY** (Only Series 525 and 625 (≥ 1/8" thickness)) | | |
| Flammability Classification | UL 94 | V-0 |
| Tunnel Test | ASTM E84 | 25 Max |
| NBS Smoke Chamber | ASTM E662 | 650-700 (Typical) |
| Flammability | ASTM D635 | Self Extinguishing |
| UL Thermal Index | Generic | 266°F |
| British Fire Test | BS 476-7 | Class 1 |

LW — lengthwise
CW — crosswise
PF — perpendicular to laminate face

**NOTES:**

① Refer to Section 9 — **COMPRESSION MEMBERS** for the recommended allowable stresses for **EXTREN®** columns.

② Refer to Section 8 — **FLEXURAL MEMBERS** for the recommended allowable stresses for **EXTREN®** beams. LW results are for the flange only.

③ This value is determined from full section simple beam bending of **EXTREN®** structural shapes and will be used in Sections 8 and 9 for design.

④ The Shear Modulus value has been determined from tests with full sections of **EXTREN®** structural shapes. Less precise values are occasionally estimated for pultrusion by using an equation for isotropic materials, $G=E/[2(1+\nu)]$. For example, if **EXTREN®** pultrusions are assumed to be isotropic with a Poisson's Ratio ($\nu$) of 0.33 and a Modulus of Elasticity of $2.6 \times 10^6$ psi, then G = 977,000 psi, which exceeds the listed tested value. **EXTREN®** shapes are mat/roving composites and anisotropic.

⑤ Strongwell incorporates a synthetic surfacing veil routinely on the surface of all **EXTREN®** structural shapes. This has the effect of lowering the measured Barcol Hardness and does not reflect an absence of cure. Other additives incorporated into the composite for corrosion protection and surface improvements may also reduce Barcol Hardness to a typical value of 45. A surface unprotected by a surfacing veil without additives would have a minimum value of 50.

⑥ Measured as a percentage maximum by weight.

⑦ Span to depth ratio of 3:1; **EXTREN®** angles will have a minimum value of 4,000 psi and the I/W shapes are tested in the web.

⑧ Typical values.

⑨ This is a typical value which varies with composite thickness.

# SERIES 500/525 PLATE ULTIMATE COUPON PROPERTIES

Below are the test results for the minimum ultimate coupon properties of **EXTREN®** Series 500/525 plate as per the referenced ASTM procedures. Designers should refer to Section 10 — **PLATE** for the recommended design equations for **EXTREN®**. The actual geometry and application of the plate will determine its ultimate usability.

| PROPERTY | ASTM TEST | UNITS | THICKNESS 1/8" | 3/16"-3/8" | 1/2"-1" |
|---|---|---|---|---|---|
| **MECHANICAL** | | | | | |
| Tensile Stress, LW | D638 | psi | 20,000 | 20,000 | 20,000 |
| Tensile Stress, CW | D638 | psi | 7,500 | 10,000 | 10,000 |
| Tensile Modulus, LW | D638 | $10^6$ psi | 1.8 | 1.8 | 1.8 |
| Tensile Modulus, CW | D638 | $10^6$ psi | 0.7 | 0.9 | 1.0 |
| Compressive Stress, Edgewise, LW | D695 | psi | 24,000 | 24,000 | 24,000 |
| Compressive Stress, Edgewise, CW | D695 | psi | 15,500 | 16,500 | 20,000 |
| Compressive Modulus, Edgewise, LW | D695 | $10^6$ psi | 1.8 | 1.8 | 1.8 |
| Compressive Modulus, Edgewise, CW | D695 | $10^6$ psi | 0.7 | 0.9 | 1.0 |
| Flexural Stress, Flatwise, LW | D790 | psi | 24,000 | 24,000 | 24,000 |
| Flexural Stress, Flatwise, CW | D790 | psi | 10,000 | 13,000 | 17,000 |
| Flexural Modulus, Flatwise, LW | D790 | $10^6$ psi | 1.1 | 1.1 | 1.4 |
| Flexural Modulus, Flatwise, CW | D790 | $10^6$ psi | 0.8 | 0.8 | 1.3 |
| Modulus of Elasticity, LW | Full Section | $10^6$ psi | 2.0 | 2.0 | 2.0 |
| Modulus of Elasticity, CW | Full Section | $10^6$ psi | 0.8 | 0.8 | 1.3 |
| Ultimate Bearing Stress, LW | D953 | psi | 32,000 | 32,000 | 32,000 |
| Poisson's Ratio, LW ② | D3039 | in/in | 0.31 | 0.31 | 0.31 |
| Poisson's Ratio, CW ② | D3039 | in/in | 0.29 | 0.29 | 0.29 |
| Notched Izod Impact, LW | D256 | ft-lbs/in | 15 | 10 | 10 |
| Notched Izod Impact, CW | D256 | ft-lbs/in | 5 | 5 | 5 |
| **PHYSICAL** | | | | | |
| Barcol Hardness | D2583 | — | 40 | 40 | 40 |
| 24 hr. Water Absorption ① | D570 | % Max | 0.60 | 0.60 | 0.60 |
| Density | D792 | $lbs/in^3$ | 0.060-0.068 | 0.060-0.068 | 0.060-0.068 |
| Coefficient of Thermal Expansion ② | D696 | $10^{-6}$ in/in/°F | 8 | 8 | 8 |
| **ELECTRICAL** | | | | | |
| Dielectric Strength, LW ② | D149 | KV/in | 35 | 35 | 35 |
| Dielectric Strength, PF ② | D149 | volts/mil | 200 | — | — |

LW — lengthwise
CW — crosswise
PF — perpendicular to the laminate face

**NOTES:**
① Measured as a percentage maximum by weight.
② This is a typical value which varies with composite thickness.

# SERIES 600/625 PLATE ULTIMATE COUPON PROPERTIES

Below are the test results for the minimum ultimate coupon properties of **EXTREN®** Series 625 plate as per the referenced ASTM procedures. Designers should refer to Section 10 — **PLATE** for the recommended design equations for **EXTREN®**. The actual geometry and application of the plate will determine its ultimate usability.

| PROPERTY | ASTM TEST | UNITS | THICKNESS 1/8" | 3/16"-1/4" | 3/8"-1" |
|---|---|---|---|---|---|
| **MECHANICAL** | | | | | |
| Tensile Stress, LW | D638 | psi | 20,000 | 20,000 | 20,000 |
| Tensile Stress, CW | D638 | psi | 7,500 | 10,000 | 10,000 |
| Tensile Modulus, LW | D638 | $10^6$ psi | 1.8 | 1.8 | 1.8 |
| Tensile Modulus, CW | D638 | $10^6$ psi | 1.0 | 1.0 | 1.0 |
| Compressive Stress, Edgewise, LW | D695 | psi | 24,000 | 24,000 | 24,000 |
| Compressive Stress, Edgewise, CW | D695 | psi | 16,500 | 17,500 | 17,500 |
| Compressive Modulus, Edgewise, LW | D695 | $10^6$ psi | 1.8 | 1.8 | 1.8 |
| Compressive Modulus, Edgewise, CW | D695 | $10^6$ psi | 1.0 | 1.0 | 1.0 |
| Flexural Stress, Flatwise, LW | D790 | psi | 24,000 | 24,000 | 24,000 |
| Flexural Stress, Flatwise, CW | D790 | psi | 10,000 | 13,000 | 17,000 |
| Flexural Modulus, Flatwise, LW | D790 | $10^6$ psi | 1.1 | 1.1 | 1.4 |
| Flexural Modulus, Flatwise, CW | D790 | $10^6$ psi | 0.8 | 0.9 | 1.3 |
| Modulus of Elasticity, LW | Full Section | $10^6$ psi | 2.0 | 2.0 | 2.0 |
| Modulus of Elasticity, CW | Full Section | $10^6$ psi | 0.8 | 0.9 | 1.3 |
| Ultimate Bearing Stress, LW | D953 | psi | 32,000 | 32,000 | 32,000 |
| Poisson's Ratio, LW ② | D3039 | in/in | 0.32 | 0.32 | 0.32 |
| Poisson's Ratio, CW ② | D3039 | in/in | 0.24 | 0.24 | 0.24 |
| Notched Izod Impact, LW | D256 | ft-lbs/in | 15 | 10 | 10 |
| Notched Izod Impact, CW | D256 | ft-lbs/in | 5 | 5 | 5 |
| **PHYSICAL** | | | | | |
| Barcol Hardness | D2583 | — | 40 | 40 | 40 |
| 24 hr. Water Absorption ① | D570 | % Max | 0.60 | 0.60 | 0.60 |
| Density | D792 | $lbs/in^3$ | 0.060-0.068 | 0.060-0.068 | 0.060-0.068 |
| Coefficient of Thermal Expansion ② | D696 | $10^{-6}$ in/in/°F | 8 | 8 | 8 |
| **ELECTRICAL** | | | | | |
| Dielectric Strength, LW ② | D149 | KV/in | 35 | 35 | 35 |
| Dielectric Strength, PF ② | D149 | volts/mil | 250 | — | — |

LW — lengthwise
CW — crosswise
PF — perpendicular to the laminate face

**NOTES:**
① Measured as a percentage maximum by weight.
② This is a typical value which varies with composite thickness.

# EXTREN TC® THERMAL CURE ROD AND BAR ULTIMATE COUPON PROPERTIES

**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.

Below are the test results for the **minimum** ultimate **coupon** properties of thermal cure rod and bar as per the referenced ASTM procedures. Rod and bar stock contain longitudinal reinforcements only – no mat. Coupon testing provides a proof test for the composite, but the actual geometry and application of the structural shape will determine its ultimate usability.

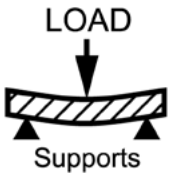
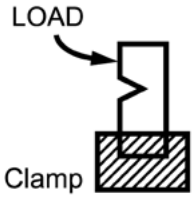
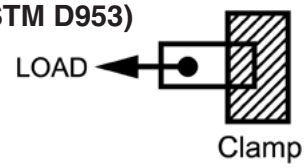
| PROPERTY | ASTM TEST | UNITS | THERMAL CURE CLEAR |
|---|---|---|---|
| **MECHANICAL** | | | |
| Tensile Stress, LW | D3916 | psi | 100,000 |
| Tensile Modulus, LW | D3916 | $10^6$ psi | 6.0 |
| Compressive Stress, Axial, LW | D695 | psi | 60,000 |
| Flexural Stress, LW | D790 | psi | 100,000 |
| Flexural Modulus, LW | D790 | $10^6$ psi | 6.0 |
| Notched Izod Impact, LW | D256 | ft-lbs/in | 40 |
| Short Beam Shear, LW | D4475 | psi | 5,500 |
| **PHYSICAL** | | | |
| Barcol Hardness | D2583 | — | 50 |
| 24 hr. Water Absorption ① | D570 | % Max | 0.25 |
| Density | D792 | $lbs/in^3$ | 0.072-0.076 |
| Coefficient of Thermal Expansion ② | D696 | $10^{-6}$ in/in/°F | 5 |
| **ELECTRICAL** | | | |
| Dielectric Strength, LW ② | D149 | KV/in | 35 |

LW — lengthwise or parallel to the roving

**NOTE:** All thermal cure rod and bar are not normally produced with a fire retardant resin. Thermal cure rod and bar were not designed to be machined. Machining may cause splintering or other issues due to the lack of off-axis reinforcements.

① Measured as a percentage maximum by weight.
② Typical values.

# DESCRIPTION OF TESTS FOR EXTREN®

| TEST | DESCRIPTION |
|---|---|
| **TENSILE STRENGTH (ASTM D638)**<br>  | 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)**<br>  | 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)**<br>  | 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)**<br>  | 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)**<br>  | 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. |

# DESCRIPTION OF TESTS FOR EXTREN®

**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.