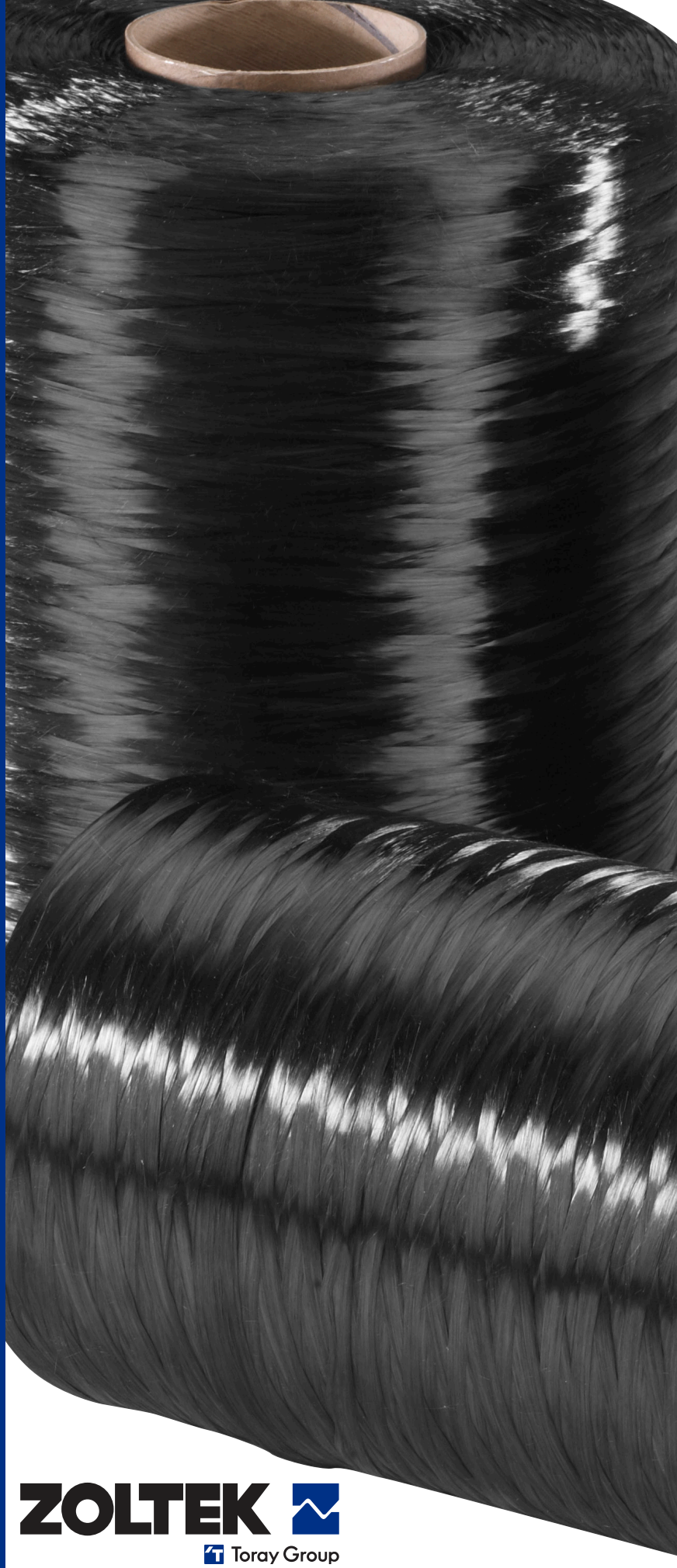
ZOLTEK PX35 COMMERCIAL CARBON FIBER



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ZOLTEK PX35

In the world of materials, ZOLTEK PX35 has emerged as the industrial carbon fiber - one that is both affordable and delivers the strength to weight performance equal to or better than many “aerospace” grades.

ZOLTEK PX35 reinforced composites are remarkable in their performance characteristics and properties that include: high strength, low weight, high stiffness, corrosion resistance, heat resistance, and electrical conductivity.

ZOLTEK PX35 is made from our abundant textile-based precursor and manufactured in a proprietary high-throughput process that allows it to be the lowest cost commercial carbon fiber on the market.

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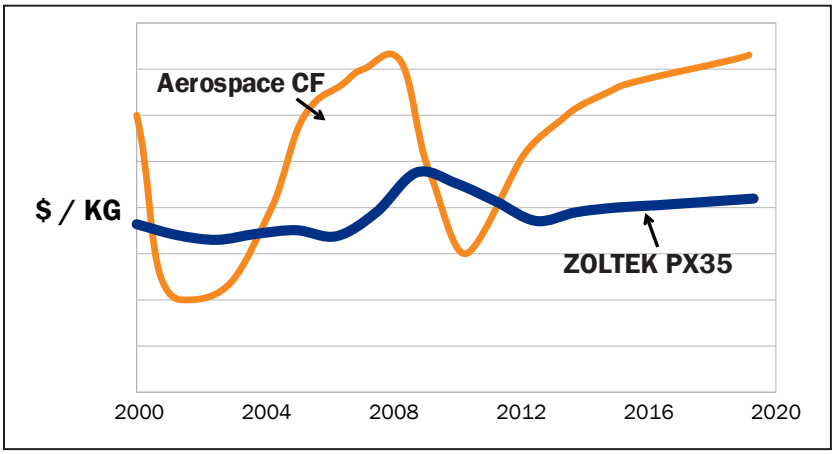
THE ZOLTEK ADVANTAGE

LOW-COST PRODUCTION

ZOLTEK PX35 carbon fiber is created from a textile-type precursor. Combined with a high-throughput process, ZOLTEK PX35 is the best value carbon fiber in production.

CAPACITY FOR EXPANSION

ZOLTEK has a demonstrated ability to expand at the rate necessary for the commercialization of new applications. With the lowest cost capital investment in the industry, turnkey production expansions happen in as little as six months.



STABLE PRICING STRUCTURE

A unique position in the marketplace ensures price stability needed to sustain customers' operations and growth. ZOLTEK carbon fiber is not dependent on the volatile aerospace industry.

QUALITY AND PERFORMANCE

Commercial carbon fiber has a record of product consistency and reliable performance properties. Employee commitment and ISO, AS, and QS certifications all contribute to ZOLTEK products meeting and exceeding the needs and requirements of customers.

VALUE ADDED INTERMEDIATE PRODUCTS

With the ability to produce carbon fiber in a variety of forms including pultrusion, fabric, and chopped fibers, ZOLTEK has a product that is right for your needs.

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APPLICATIONS

ZOLTEK PX35 carbon fiber has market-leading properties at a market-leading price. ZOLTEK products are increasing the energy output of wind turbines, creating more fuel efficient vehicles, and lifting other industries to new levels of performance.

Automotive - Our cost-effective solutions and our ability to provide long-term price and supply commitments has many automotive manufacturers turning to ZOLTEK as a resource for increasing the efficiency and value-structure of their processes.

Wind Energy - ZOLTEK PX35 carbon fiber is the industry standard for carbon fiber wind energy reinforcement.

Friction Resistance - Our carbon braking materials are manufactured to withstand extreme braking conditions that demand resistance to harsh temperature and chemical environments.

Civil Engineering - ZOLTEK PX35 fabrics are often utilized in the repair or upgrade of concrete structures including bridges, columns, and beams.

Marine - Tough, durable carbon composite materials stand up to the extremes of marine environments.

Energy Storage - Carbon fiber based energy storage solutions balance power and energy output with grid demand and allow for energy generation and transmission optimization.

Sporting Goods - The high-strength, high modulus and light-weight properties of carbon fiber have taken sporting goods to the next level of performance.

3D Printing - Our carbon fiber enables the production of cost-efficient filament for the manufacture of structural production parts and prototypes.

Oil & Gas - ZOLTEK's deepwater products provide less weight and more stiffness and strength to deepwater oil exploration – enabling deepwater systems to operate at depths unreachable with traditional materials.

Pressure Vessels - The benefits of carbon fiber as a light-weight alternative to other materials combined with its durability and corrosion resistance properties have been driving innovation for decades.

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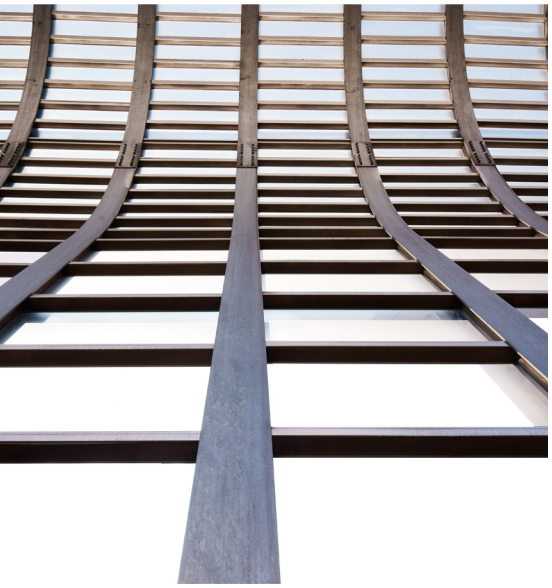
APPLICATIONS



Zoltek products for a variety of applications.

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CONTINUOUS TOW

ZOLTEK PX35 Continuous Tow is the premier commercial carbon fiber on the market. It is a 50,000 filament fiber manufactured from polyacrylonitrile (PAN) precursor, and is available with a range of sizings for optimal processing and compatibility with a variety of resin systems. ZOLTEK employs a quality system focused on spool-to-spool consistency yielding low coefficients of variation.

- **DNV-GL Approved**
- **Processing Support Available**
- **Spool to Spool Consistency**

MATERIAL OVERVIEW	SI	US
Tensile Strength	4,137 MPa	600 ksi
Tensile Modulus	242 GPa	35 msi
Elongation	1.5%	
Electrical Resistivity	0.00155 ohm-cm	0.00061 ohm-in
Density	1.81 g/cc	0.065 lb/in^3
Fiber Diameter	7.2 microns	0.283 mils
Carbon Content	95%	

The properties listed herein do not constitute any warranty or guarantee of values. This information should only be used for the purposes of material selection. Please contact us for more details.

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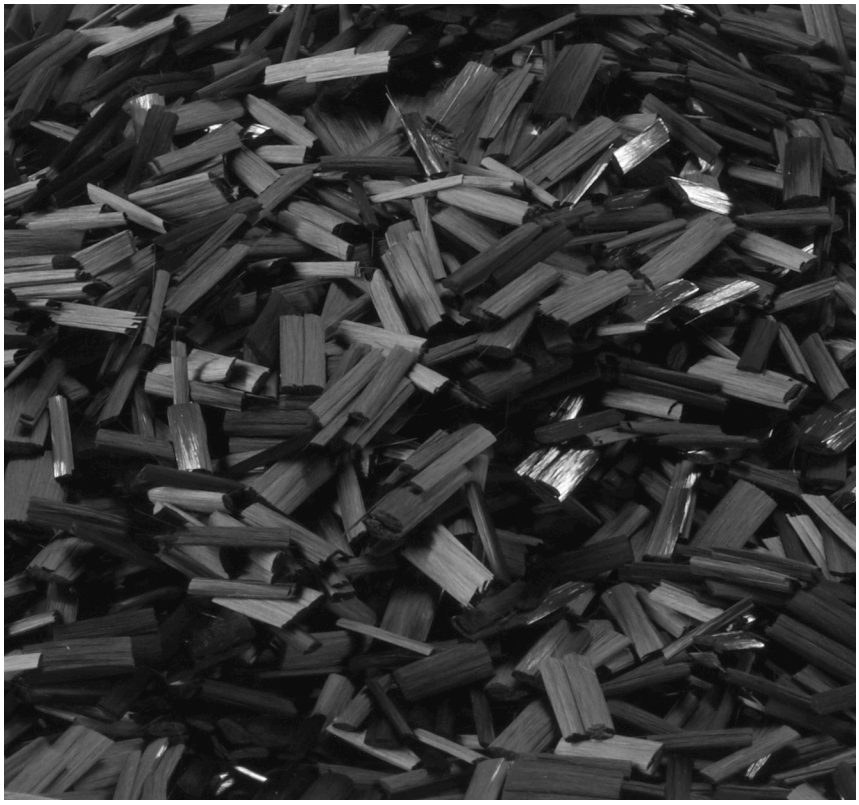
CHOPPED

ZOLTEK PX35 Chopped Fiber is commonly compounded with general engineering thermoplastics (e.g., PC, Nylon, etc.) and high-temperature thermoplastic resins (e.g, PEEK, PEI, etc.). The resulting composite offers high strength-to-weight and stiffness-to-weight ratios. Our chopped fibers have a high bulk density value, which allows for cleaner and more consistent flow rates. They also distribute easily during compounding, thereby improving process and product performance. Our chopped fibers are available in a pellet, flake, or stick form.



- **High Bulk Density Value**
- **Clean, Consistent Flow Rates**
- **Easy Distribution**
- **Improves Product Performance**

FIBER TYPE	RECOMMENDED USE	UNPACKED BULK DENSITY (MINIMUM)	FIBER LENGTH (NOMINAL)
-02	Water-Based Slurry Type	N/A	3, 6, 13, 25, & 50 mm (0.125, 0.25, 0.5, 1.0, & 2.0 in)
-13	Epoxy, Vinyl Ester, Unsaturated Polyester, and Phenolic	350 g/L (22lb/ft^3)	3, 6, & 13 mm (0.125, 0.35, & 0.5 in)
-45	ABS, PET, POM, PA, PA66	425 g/L (26.5lb/ft^3)	6 mm (0.25 in)
-48	PBT/PET, PA (nylon)	200 g/L (12.5lb/ft^3)	8 mm (0.33 in)
-55	PP	350 g/L (22 lb/ft^3)	6 mm (0.25 in)
-65	ABS, PET, PA, PC, TPU, POM	425 g/L (26.5lb/ft^3)	6 mm (0.25 in)
-83	HPPA, PPO, PPA, PEEK, PAI, TPI	350 g/L (22lb/ft^3)	6 mm (0.25 in)
-95	PA, PA66	350 g/L (22lb/ft^3)	6 mm (0.25 in)

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KS

ZOLTEK PX35 KS fiber is ideally suited for Sheet Molding Compound (SMC) applications. Through a proprietary process, the 50K tow bundles are split into 3K sub tows. The resulting KS fiber is designed to be chopped to allow for homogeneous dispersal in SMC for compression molding applications.

The KS fiber has improved material flow, which allows for thinner molded parts with an equivalent stiffness, and sets a new benchmark for low-cost carbon fiber SMC compared to other materials like fiberglass, aluminum, and steel.

- **Highly Efficient Process**
- **Improved Consistency**
- **Improved Dispersion**
- **Available for Epoxy and Vinylester Resins**

MATERIAL OVERVIEW	SI	US
Tensile Strength	290 MPa	42.1 ksi
Tensile Modulus	35.5 GPa	5.2 msi
Flexural Strength	497 MPa	72.1 ksi
Flexural Modulus	32.2 GPa	4.7 msi
Izod Impact - Unnotched	57.9 kJ/m^2	27.6 lb/in^2

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MILLED

ZOLTEK PX35 Milled Fibers are specially processed PAN (polyacrylonitrile) based fiber suitable for high-volume applications that require strength and/or electrostatic dissipation. The ZOLTEK in-house milling system ensures product quality and traceability from raw material through the finished product.

- **Electrically Conductive**
- **Excellent Buoyancy Properties**
- **RFI/EMI Electronic Shielding**

MATERIAL OVERVIEW	SI	US
Carbon Content	95%	
Electrical Resistivity (Volume)	0.00155 Ω/cm	0.00061 Ω/in
Linear Resistivity	0.0761 Ω/cm	0.02996 Ω/in
Density	1.81 g/cc	0.065 lb/in^3
Bulk Density	490 g/L	30.6 lb/ft^3
Fiber Diameter	7.2 µm	0.283 mils
Average Fiber Length	100 µm (MF150) 150 µm (MF200)	4 mils (MF150) 6 mils (MF200)

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UNIDIRECTIONAL FABRIC

ZOLTEK PX35 Stitch-Bonded Unidirectional Carbon Fabrics are produced from our ZOLTEK PX35 50K Continuous Tow Carbon Fiber. Unique fiber spreading techniques are utilized to obtain a wide range of UD fabric weights for a varied set of composite part applications. Quick composite part build-up is cost effectively achieved with our diverse weight range of low-cost carbon fabric products.

- **Ideal for Rapid Build-Up of Part Thickness**
- **DNV-GL Approved**

MATERIAL OVERVIEW	SI	US
Tensile Strength	1400 MPa	203 ksi
Tensile Modulus	119 GPa	17.2 msi
Compressive Strength	980 MPa	142 ksi
Compressive Modulus	118 GPa	17.5 msi
Flexural Strength	1290 MPa	187 ksi
Flexural Modulus	112 GPa	16.2 msi

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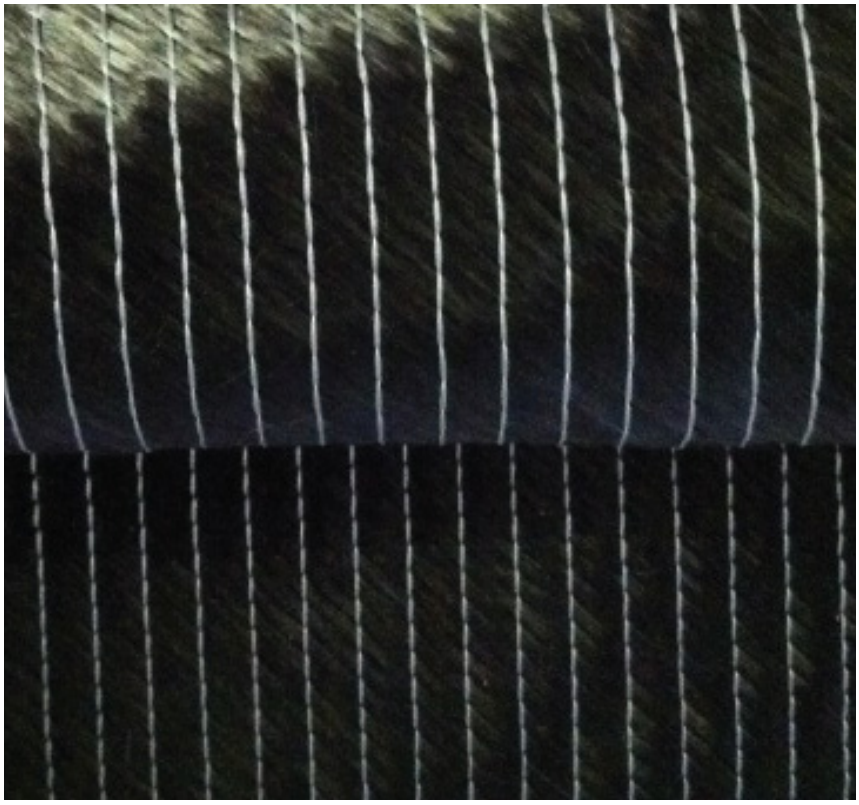
MULTI-DIRECTIONAL FABRIC

ZOLTEK PX35 Multi-Directional Fabric is produced from our ZOLTEK PX35 Continuous Carbon Fiber Tow. Unique fiber spreading techniques are utilized to obtain a wide range of Multi-Directional fabric weights for a varied set of composite part applications. Quick composite part build-up is cost effectively achieved with our diverse weight range of low-cost carbon fabric products. Pillar and Tricot stitching patterns are available for complex shape preforms.



- **Constructed for Enhanced Drapability**
- **Ideal for Complex Shape Preforms**

MATERIAL OVERVIEW	SI	US
Tensile Strength	4137 MPa	600 ksi
Tensile Modulus	242 GPa	35 msi
Electrical Conductivity	0.00155 Ω/cm	0.00061 Ω/cm
Density	181 g/cc	0.065 lb/in^3
Fiber Diameter	7.2 µm	0.283 mils
Carbon Content	95%	

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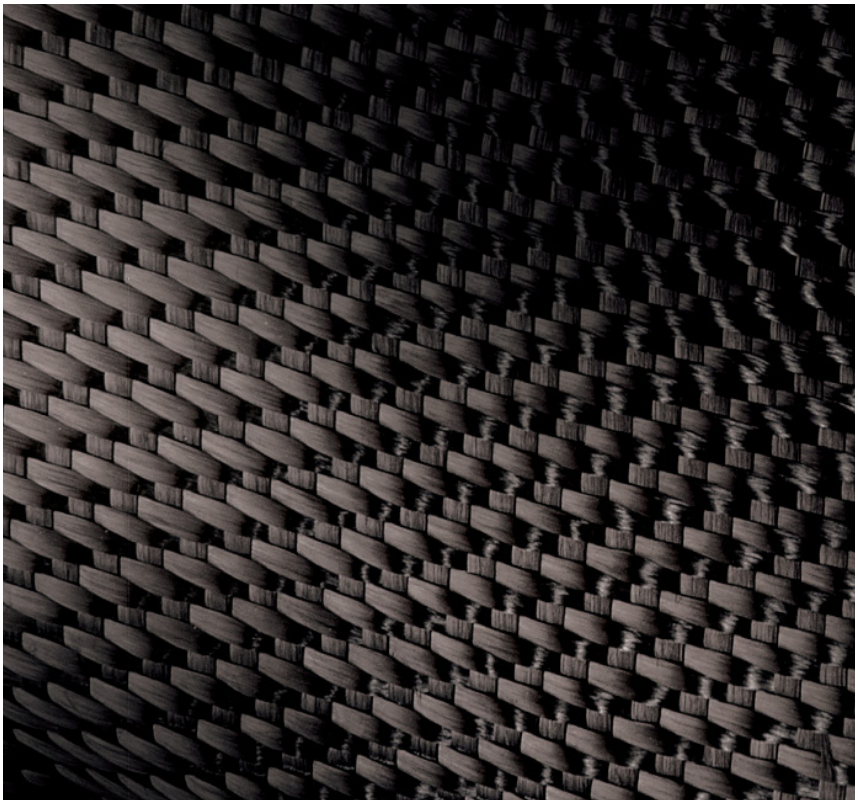
WOVEN FABRIC



ZOLTEK PX35 Woven Carbon Fabrics are produced from our ZOLTEK PX35 50K Continuous Tow Carbon Fiber. Quick composite part build-up is cost effectively achieved with our attractive carbon fiber fabrics. Applications include large composite tooling parts and aesthetically appealing finished composite components.

- **Ideal for Applications Where Durability is Required**

MATERIAL OVERVIEW	P/TW28-50		SW48-50	
	SI	US	SI	US
Construction	Plain or Twill Weave		5 Harness Satin Weave	
Warp Yarn	1/cm	2.6/in	2/cm	5.1/in
Fill Yarn	1.5/cm	3.8/in	2.4/cm	6.1/in
Areal Weight	960 g/m^2	28 oz/yd^2	1640 g/m^2	48.4 oz/yd^2
Width	1270 mm	50 in	1270 mm	50 in
Thickness	1.5 mm	0.055 in	2.38 mm	0.093 in
Roll Length	30 m	32.8 yd	25 m	27.3 yd
Yarn	ZOLTEK PX35 50K Tow with Epoxy Sizing at 1.5%			

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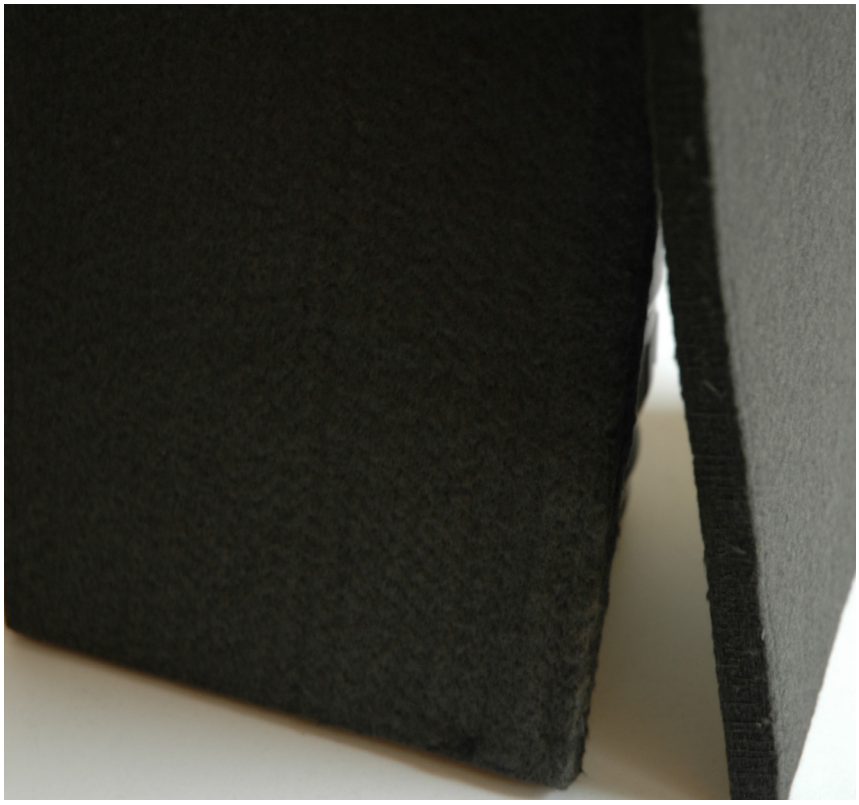
FELT

Produced from 100% ZOLTEK OX oxidized PAN fibers and later carbonized in our vacuum furnaces, ZOLTEK PX35 carbon felt is widely used. Current applications include insulation in high temperature furnaces. Unique properties of our ZOLTEK PX35 carbon felts are invaluable when searching for solutions in complex thermal, corrosive, or conductive applications.



- **Ideal for Thermal Insulation**
- **Uniquely Suited for Energy Storage**

MATERIAL OVERVIEW	SI	US
Carbon Content	95%	
Width	98 cm	35 in
Weight	1035 g/m^2	30 oz/yd^2
Thickness	10 mm	0.4 in
Density	0.102 g/cc	0.00368 lb/in^3
Roll Length	45 m	50 yds
Thermal Conductivity @ 23°C	0.031 W/m*K	0.21 Btu*in/hr*ft*F
Thermal Conductivity @ 600°C	0.07 W/m*K	0.51 Btu*in/hr*ft*F
Specific Heat @ 23°C	0.741 W*sec/g*K	0.099 Btu/lb*F
Specific Heat @ 600°C	0.741 W*sec/g*K	0.232 Btu/lb*F

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PULTRUSION

Pultrusion is a cost-effective, continuous process for producing fiber-reinforced composite parts. ZOLTEK PX35 Continuous Towis fed into our proprietary impregnation and curing process which creates engineered carbon fiber profiles. These profiles enable rapid section buildup when laminating thick parts such as wind blade spar caps. High fiber alignment achieved with pultrusion delivers consistently superior properties in laminates compared to any other composite manufacturing processes.

- **High Fiber Volume**
- **Low Void Content**
- **Corrosion Resistant**

PRODUCT FEATURE	PX35/VINYLESTER		PX35/EPOXY	
Fiber Volume Fraction (mean)	62%	69%	65%	69%
Flexural E Modulus (mean)	151 GPa	163 GPa	135 GPa	167 GPa
Flexural Strain (characteristic)	0.88 %	1.02 %	1.1 %	1.04 %
Interlaminar Shear Strength (characteristic)	62 MPa	67 MPa	69 MPa	71 MPa
Transverse Strength (characteristic)	72 MPa	60 MPa	62 MPa	108 MPa
Axial Tensile Modulus	141 GPa	161 GPa	144 GPa	164 GPa
Axial Compressive Modulus	133 GPa	148 GPa	135 GPa	145 GPa
Linear Tensile Strain to Failure (characteristic)	1.06%	TBD	1.2%	1.09%
Linear Compression Strain to Failure (characteristic)	0.73%	0.74%	0.75%	0.68%

** Typical data based on 5mm thick pultruded profiles*

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PREPREG

ZOLTEK produces unidirectional (UD) prepreg tapes based on PX35 carbon fiber. ZOLTEK prepreg is ideal for large-volume composite applications where high production throughput, excellent composite properties, and low material cost are important. A wide selection of epoxy resin formulations meets most processing and composite property requirements for tack, toughness, surface finish, cure time, cure temperature, and delivered composite strength and modulus. Custom formulations are also available. Packaging options include core size, customer specified kitting requirements, and custom labeling. ZOLTEK prepreg production is geared to large volumes and low cost.

- **Useful for Both Hand Layup and Automated Processes**
- **DNV-GL Approved**

MATERIAL OVERVIEW	SI	US
Tensile Strength	1850 MPa	268 ksi
Tensile Modulus	130 GPa	18.9 msi
Compressive Strength	1320 MPa	191 ksi
Compressive Modulus	125 GPa	18.1 msi
Interlaminer Shear Strength	70 MPa	10 ksi
± 45 In-Plane Shear Strength	59 MPa	8.6 ksi
± 45 In-Plane Shear Modulus	4.8 GPa	696 ksi
Glass Transition Temperature (T_g,G”)	120°C	248°F

*Depends on cure cycle.

*Typical data based on 60% Vf.

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GLOBAL FOOTPRINT

ZOLTEK has manufacturing locations producing affordable, quality carbon fiber products in Europe, Mexico, and the United States. In 2014, Zoltek joined the Toray Group – a relationship that has advanced the company's technology, strengthened its technical and financial resources, and positioned it for further growth and development as the global leader in carbon fiber.

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ABOUT ZOLTEK

Our objective as a company is to lead the commercialization of carbon fiber as a primary composite building material. It is our goal to help others achieve new levels of performance across a range of products. Carbon fiber reinforced composites are remarkable in their performance characteristics and properties that include high strength, low weight, high stiffness, corrosion resistance, heat resistance, and electrical conductivity.

Another important characteristic of carbon fiber is its versatility. Carbon fiber has the ability to work with an assortment of different materials, including other fibers, plastics, metals, wood, and concrete. As a result of this versatility, it is impossible to postulate all of the potential uses of carbon fiber in maximizing performance and lowering life-cycle costs across a range of consumer and industrial products, and across all types of construction.

ZOLTEK™ has become the worldwide leader in rated capacity for producing carbon fiber by making low-cost, high performance carbon fiber through a proprietary continuous carbonization process. Using this knowledge, it is well within our power to truly open the floodgates of demand across a variety of industries.

To learn more, visit www.zoltek.com.