



- Masterpresentation -

09/2017

Overview

1. The Pultrusion Process



2. Reinforcements



3. Resin Systems



4. Profiles & Applications



6. Sustainability



Overview

1. The Pultrusion Process



2. Reinforcements

3. Resin Systems

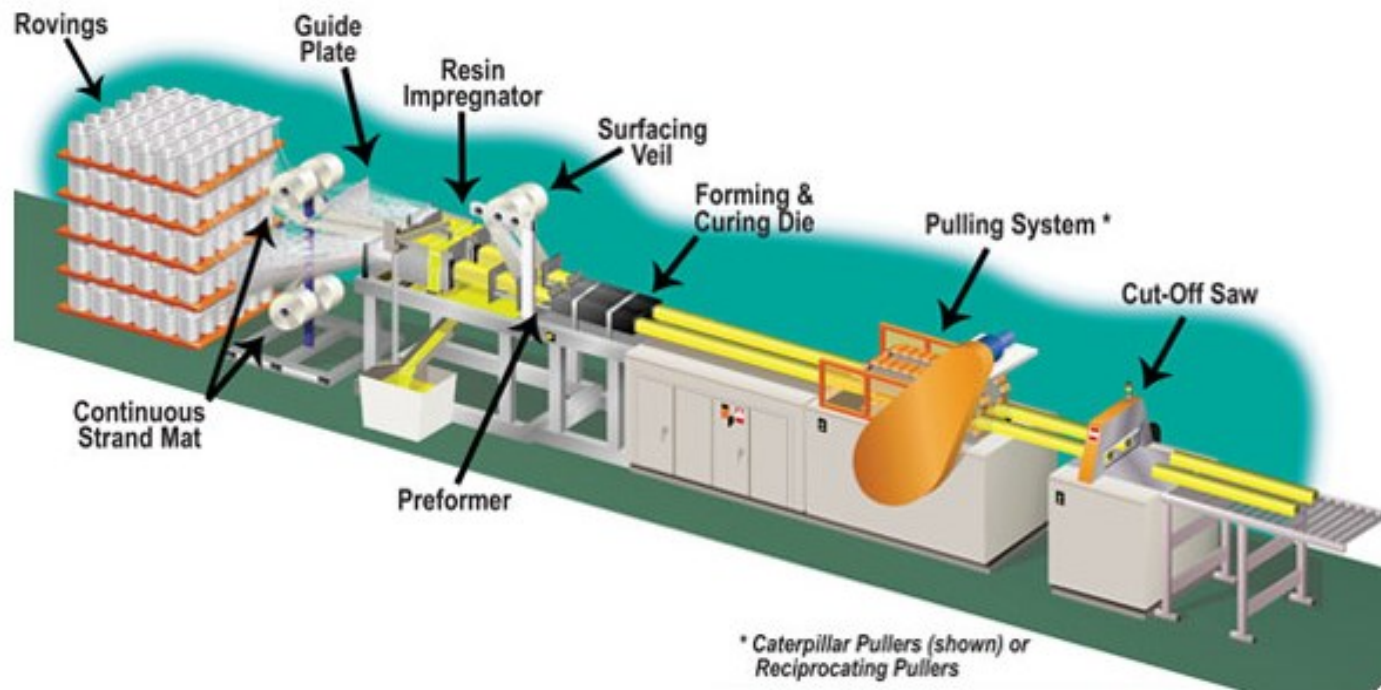
4. Profiles & Applications

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Pultrusion Process



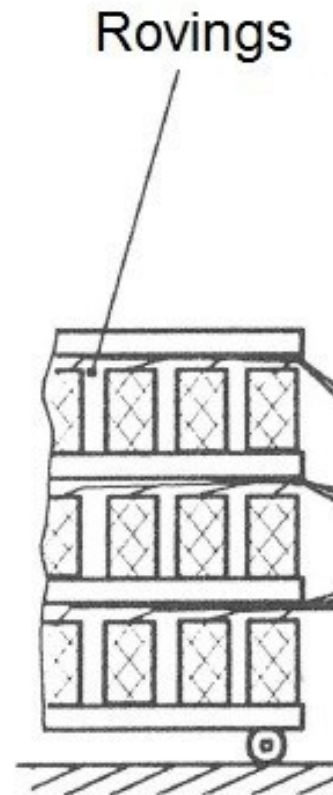
- Rovings & Mats are being impregnated, formed and cured continuously



Source: Strongwell

Bobbin Creels with Breaker Bars >>>

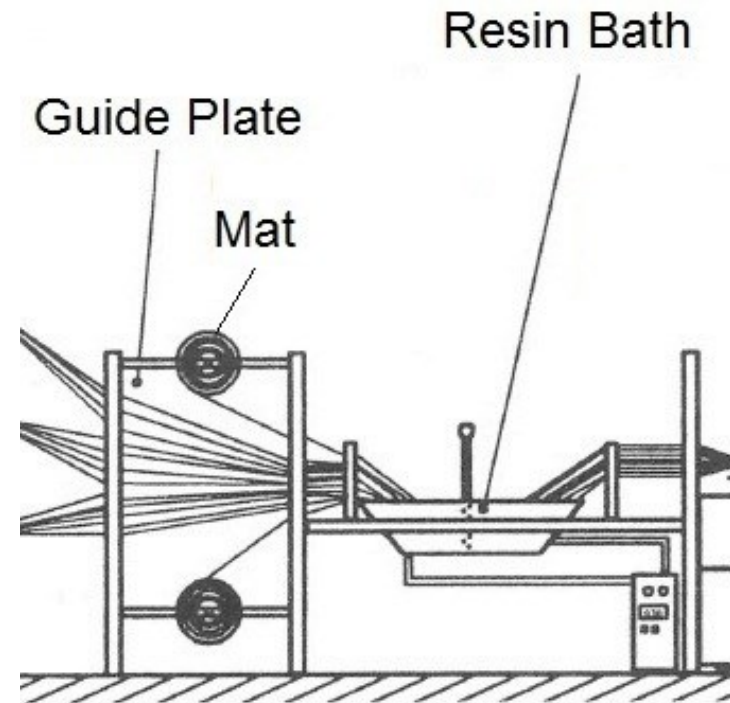
- Storing of the rovings
- Avoiding contact between the rovings
- Breaking up the sizing of the rovings (necessary for impregnation)



Source: Blaurock (literature)



- Positioning and guiding of the rovings
- Minimizing friction inbetween the rovings
- Impregnating rovings and mats
- Resin supply via pump

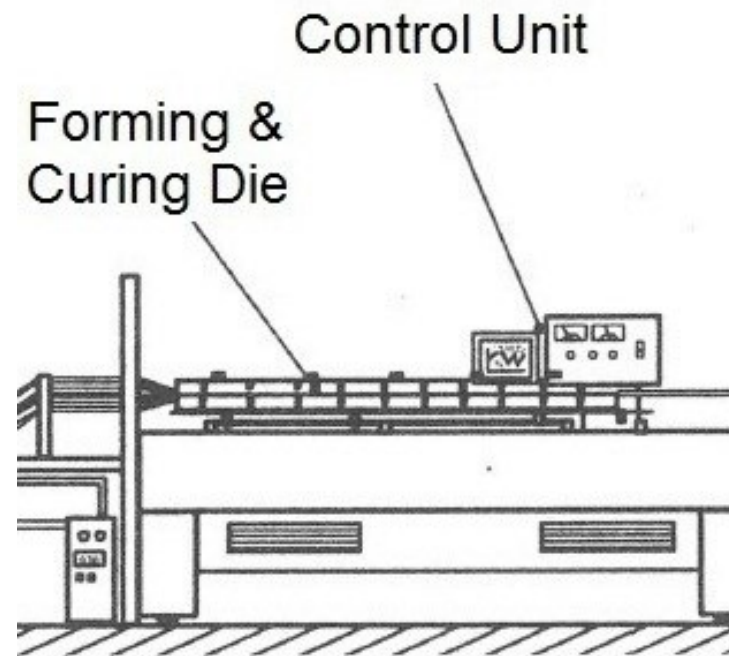


Source: Blaurock (literature)

Forming & Curing Die



- Profile forming by shape of the die
- Curing through heated die
- Heating

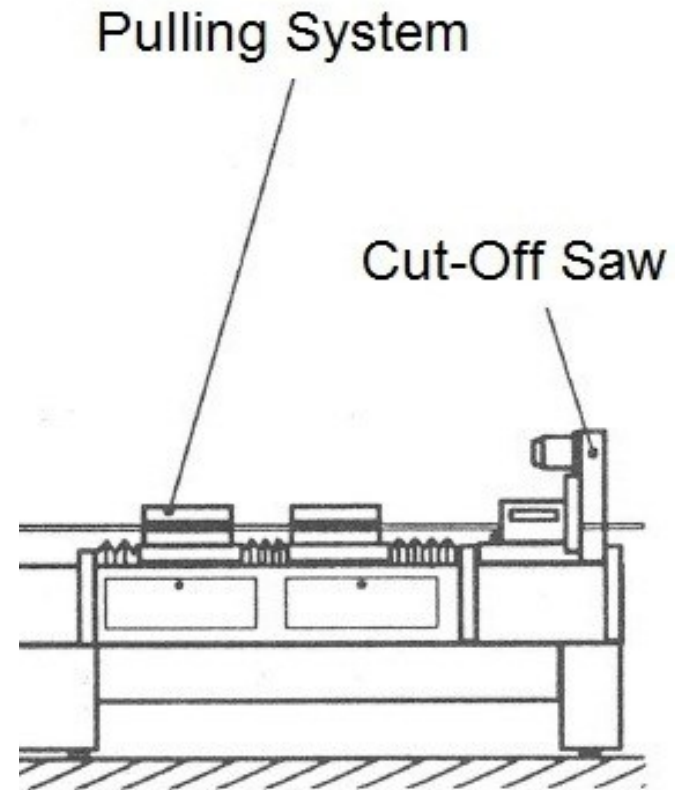


Source: Blaurock (literature)

Pulling System, Cut-Off Saw



- Pulling the profil with caterpillar or reciprocating pullers
- Cutting profiles to desired length

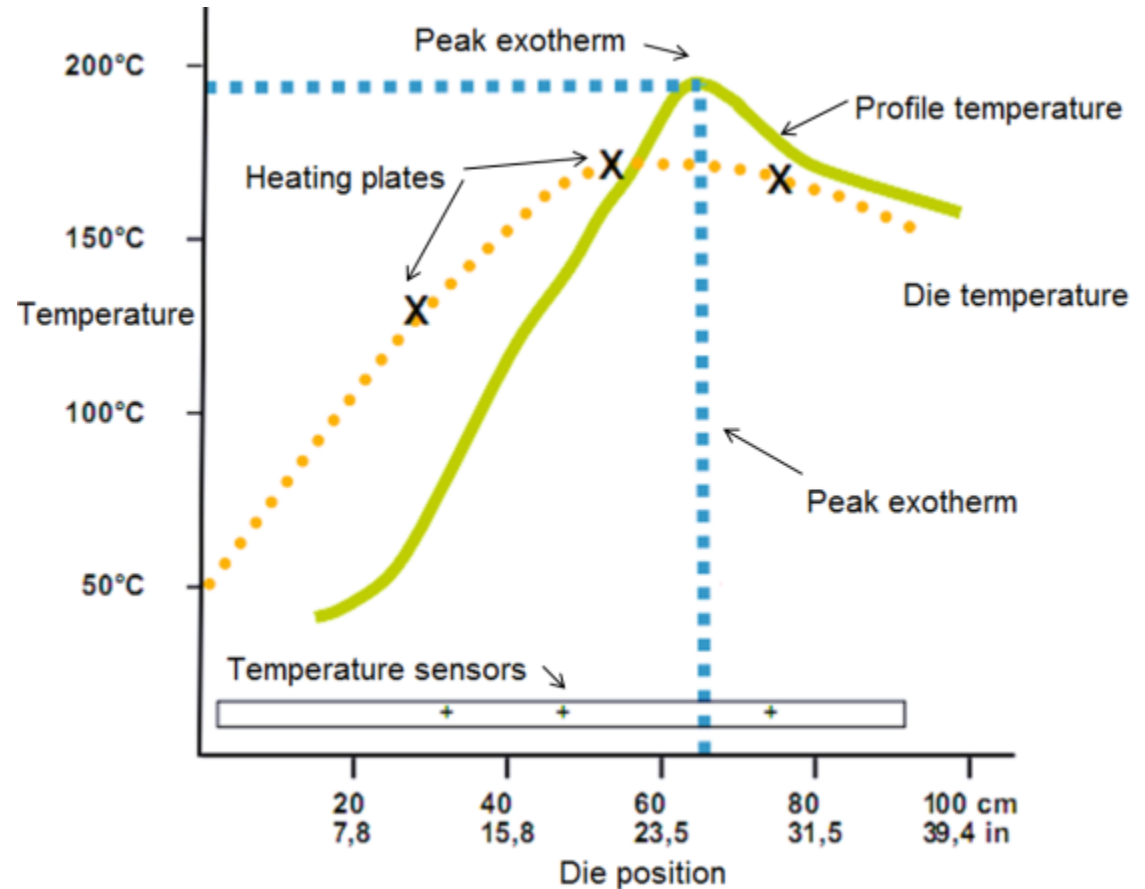


Source: Blaurock (literature)

Curing inside the die



- Initiation of an exothermic reaction in the die

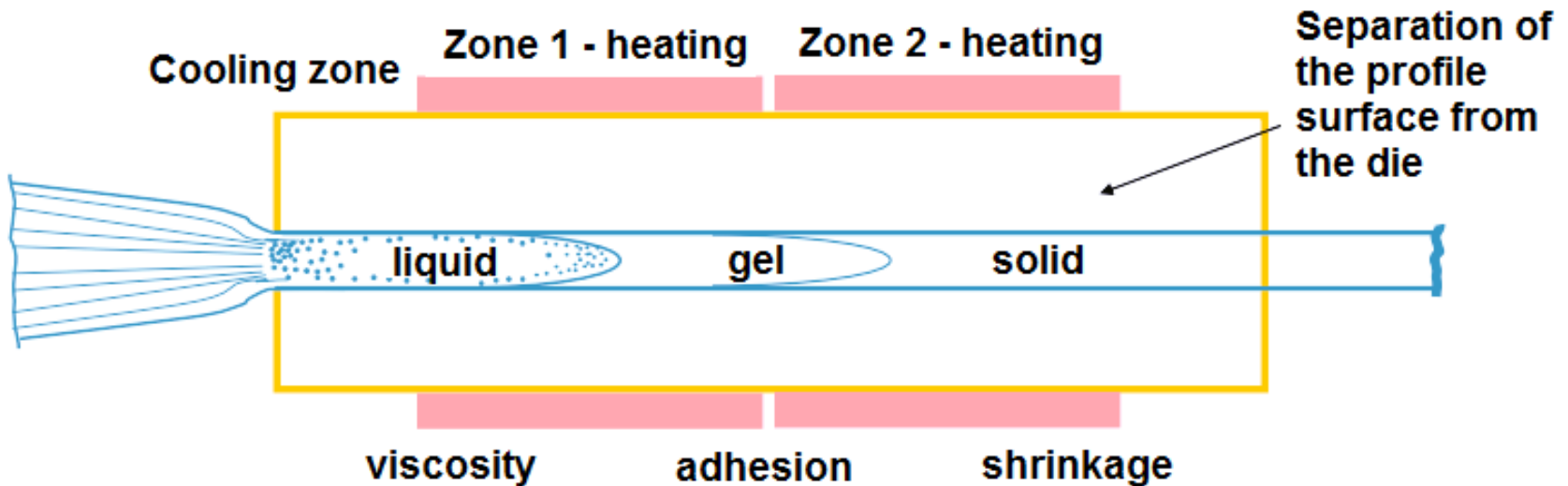


Source: Trevor (literature)

Curing in three steps



- Three steps of curing: liquid, gel, solid



Source: Trevor (literature)

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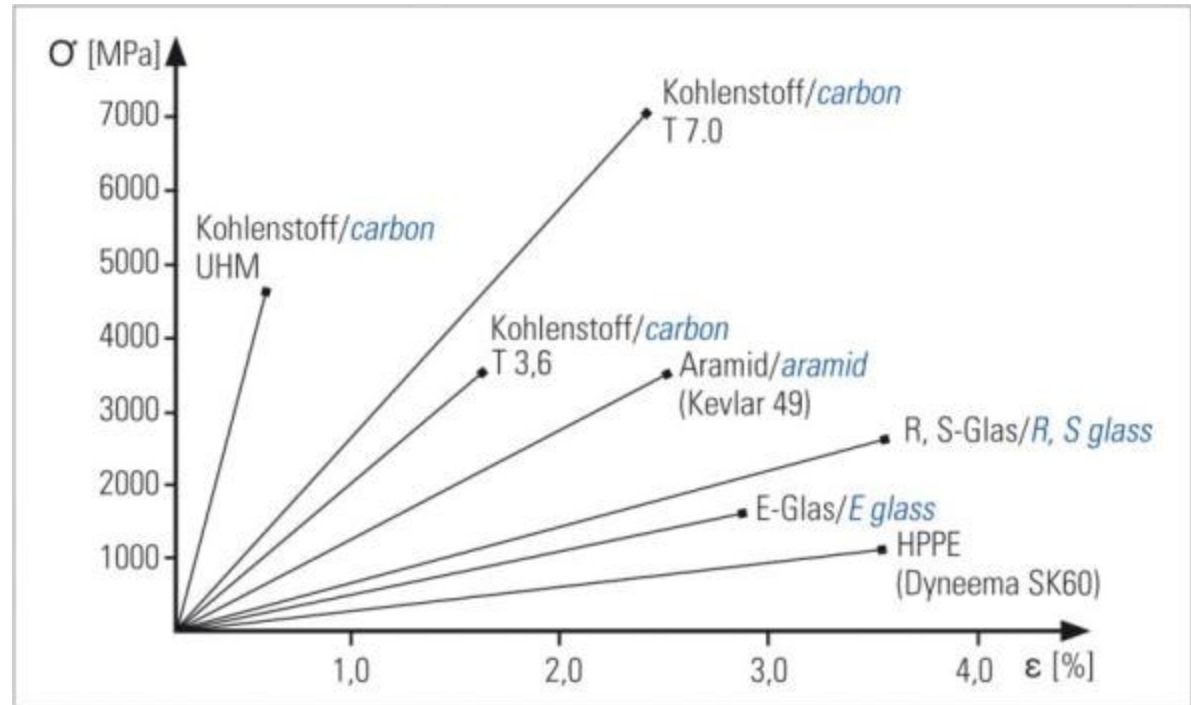
4. Profiles & Applications

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Types of Fibers



- **Glass** fibers most common
- **Carbon** fibers high performance
- **Aramid** fibers special application



Source: R&G Handbuch Faserverbundwerkstoffe, Niederstadt (literature)

Glass Fiber Advantages



- Lightweight
- Most cost-efficient
- Excellent chemical and biological resistance
- Electrical insulation
- Very high tensile strength
- Fire-Proof
- Optical transparency
- Linear elasticity with high elongation at break

Glass Fiber Types



	E-Glass	R-Glass	S-Glass	C-Glass	D-Glass
Young's Modulus [N/mm²]	73.000	86.000	86.810	71.000	55.000
Tensile Strength [N/mm²]	2.400	3.600	4.500	2.400	1.650
Thermal Expansion [10⁻⁶/°C]	5,1	4,1	5,58	7,2	3,5
Density [g/cm³]	2,54	2,55	2,49	2,51	2,14
Shear Modulus [N/mm²]	29.920		35.578		

Source: Konstruieren mit Faser-Kunststoff-Verbunden, Schürmann (literature)

Carbon Fiber Advantages



- Best mechanical properties
- Excellent stiffness and tensile strength
- Very low density
- Outstanding fatigue behaviour
- Good chemical resistance
- Negative thermal expansion

Carbon Fiber Types



	HT	ST	IM	HM	UHM
Young's Modulus [N/mm²]	230.000	245.000	294.000	392.000	450.000
Tensile Strength [N/mm²]	3.430	4.510	4.210	2.450	2.150
Thermal Expansion long. [10⁻⁶/°C]	-0,455			-0,108	
Thermal Expansion trans. [10⁻⁶/°C]	12,5			31	
Density [g/cm³]	1,74	1,8	1,74	1,81	1,9
Shear Modulus [N/mm²]	50.000			28.600	

Source: Konstruieren mit Faser-Kunststoff-Verbunden, Schürmann (literature)

Types Of Rovings



- Single-End Rovings (default)
- 300 – 9600 tex (g/km)
- Sizing promotes fiber-matrix adhesion



- Bulky Rovings
- Additional transversal strength
- Improved impregnation

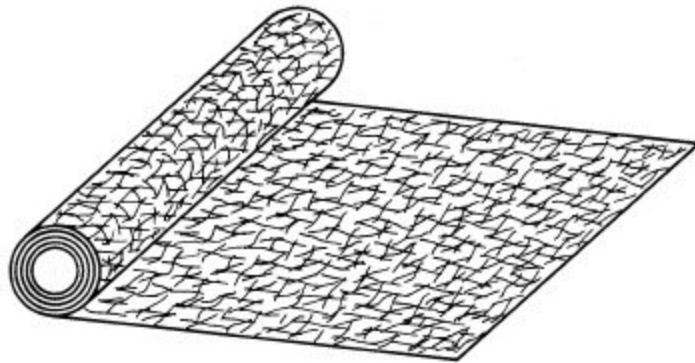


Source: OCV

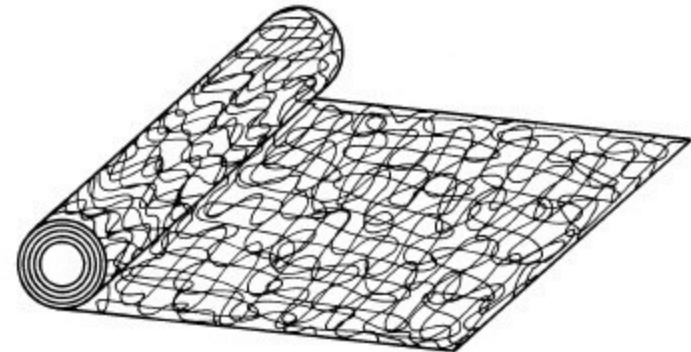
Types Of Mats



- CSM = Chopped Strand Mat + Thermoplastic Binder
- CFM = Continuous Filament Mat + Thermoplastic Binder
- Properties: Area weight (e.g. 300 g/m²), Basic Strand Diameter (e.g. 25 tex)



CSM



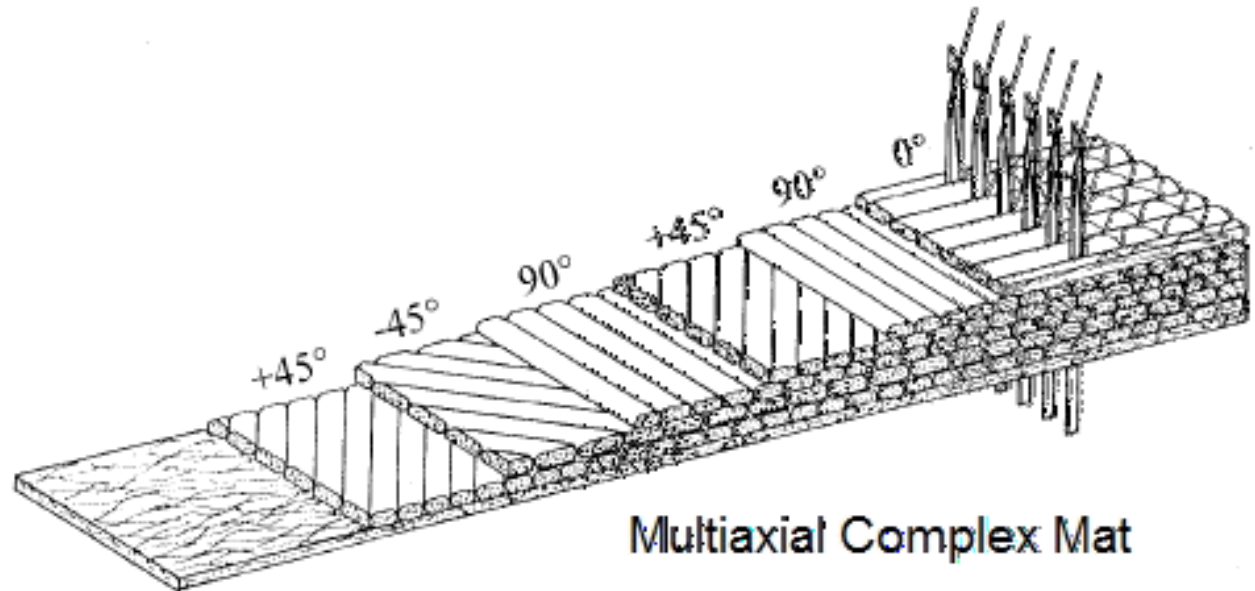
CFM

Source: Konstruieren mit Faser-Kunststoff-Verbunden, Schürmann (literature)

Types Of Mats



- Strands in various directions
- Stitched oder needled with CSM or CFM
- Gives additi

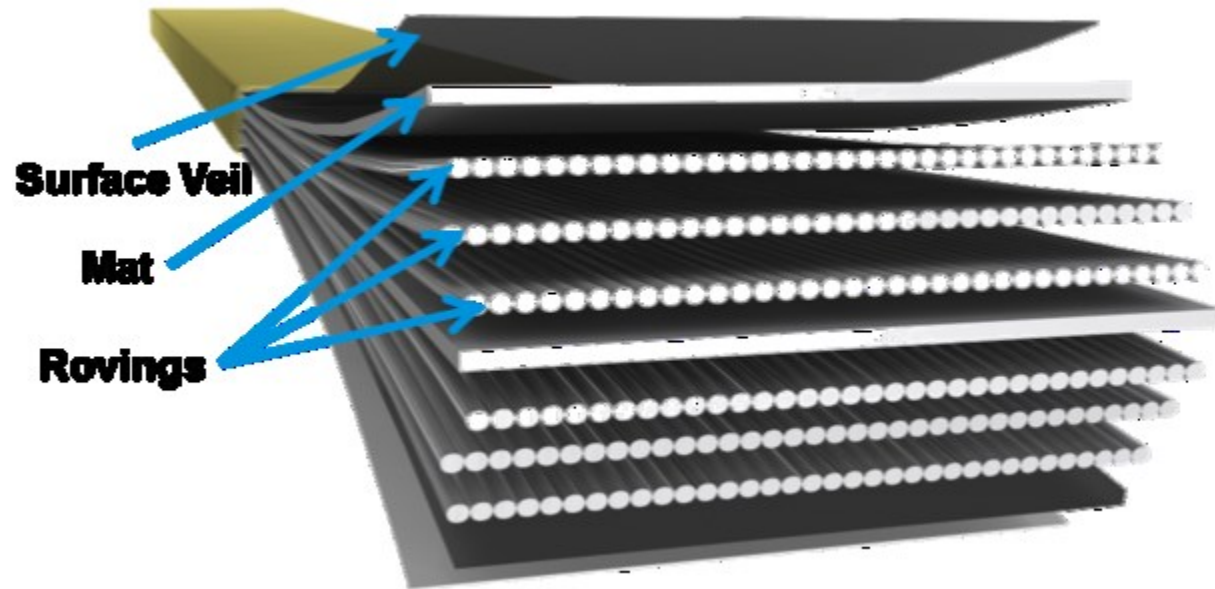


Source: Konstruieren mit Faser-Kunststoff-Verbunden, Schürmann (literature)

Typical Fiber Package



- Rovings for unidirectional reinforcement
- Mats for transversal strength
- Veil for surface quality



Source: Fraunhofer ICT

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Resin Types



- UP Resin (iso-, ortho-, terephthalic, DCPD)
- Vinyl Ester, Epoxy Resin for special applications

Resin	Tensile Strength [N/mm ²]	Young's Mod. [N/mm ²]	Break. Elong. [%]	T _G [°C]	Density [g/cm ³]
UP (Ortho)	60	4.800	2	125	1,22
Vinyl Ester	83	4.000	6	130	1,14
Epoxy	90	3.400	5	140	1,2
Polyurethane	75-85	2.700-3.000	6-12	100-160	1.18-1.23

Source: Konstruieren mit Faser-Kunststoff-Verbunden, Schürmann (literature)

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Profiles - Advantages



- Light weight
- Corrosion free
- Applicable in chemical, alkaline or acid environment
- Electrical insulation
- Thermal insulation
- Transparent for radio and radar waves
- Material properties adjustable in a wide range
- Very low life-cycle cost
- Heat resistance (dependant on matrix)
- Fatigue endurance

Profiles - Shapes

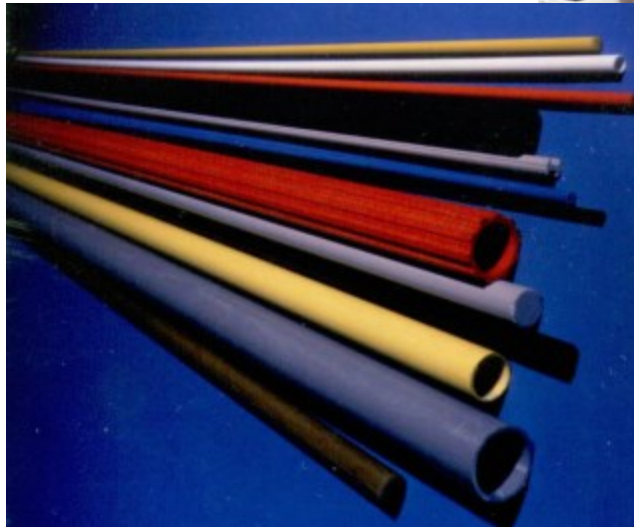


Default shapes:

- Rods
- Round Tubes
- Square tubes
- Rectangular tubes
- Flat bar
- U-channels
- Angles



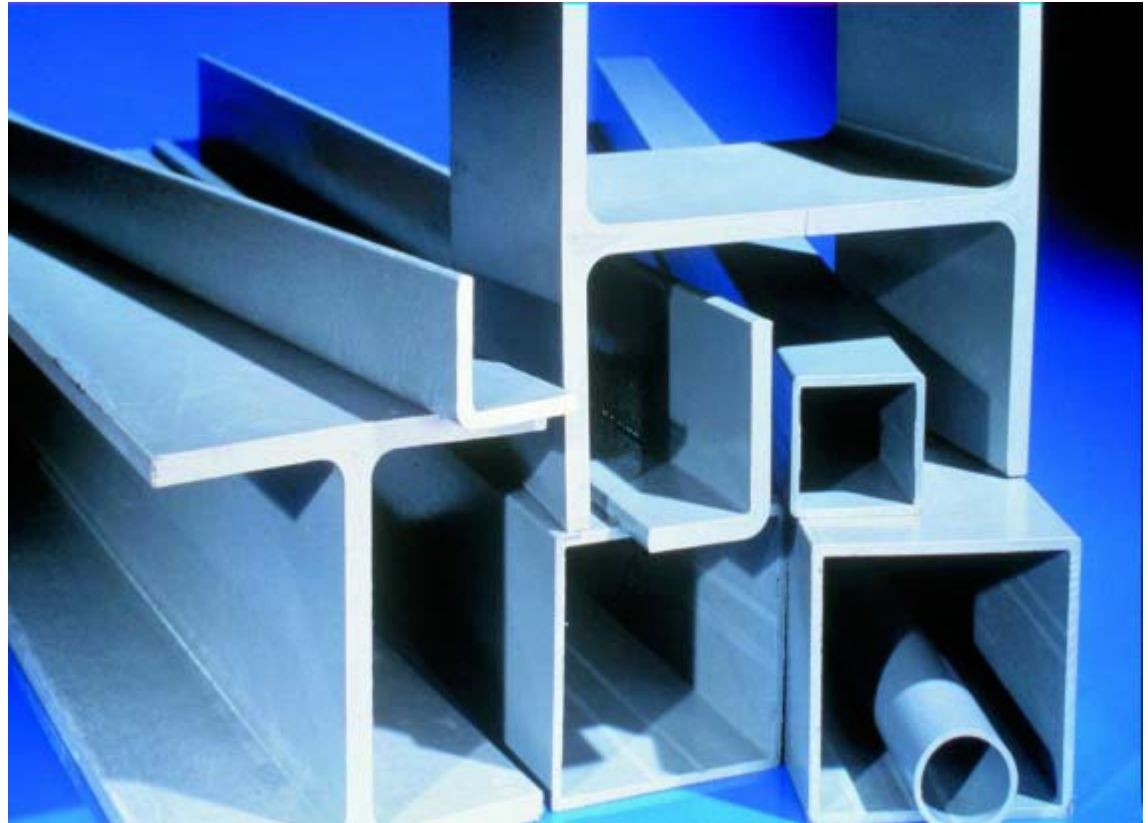
Source: Pultrex



Profiles - Shapes



- I-Beams
- L-Beams
- C-Beams
- T-Beams
- Z-Beams

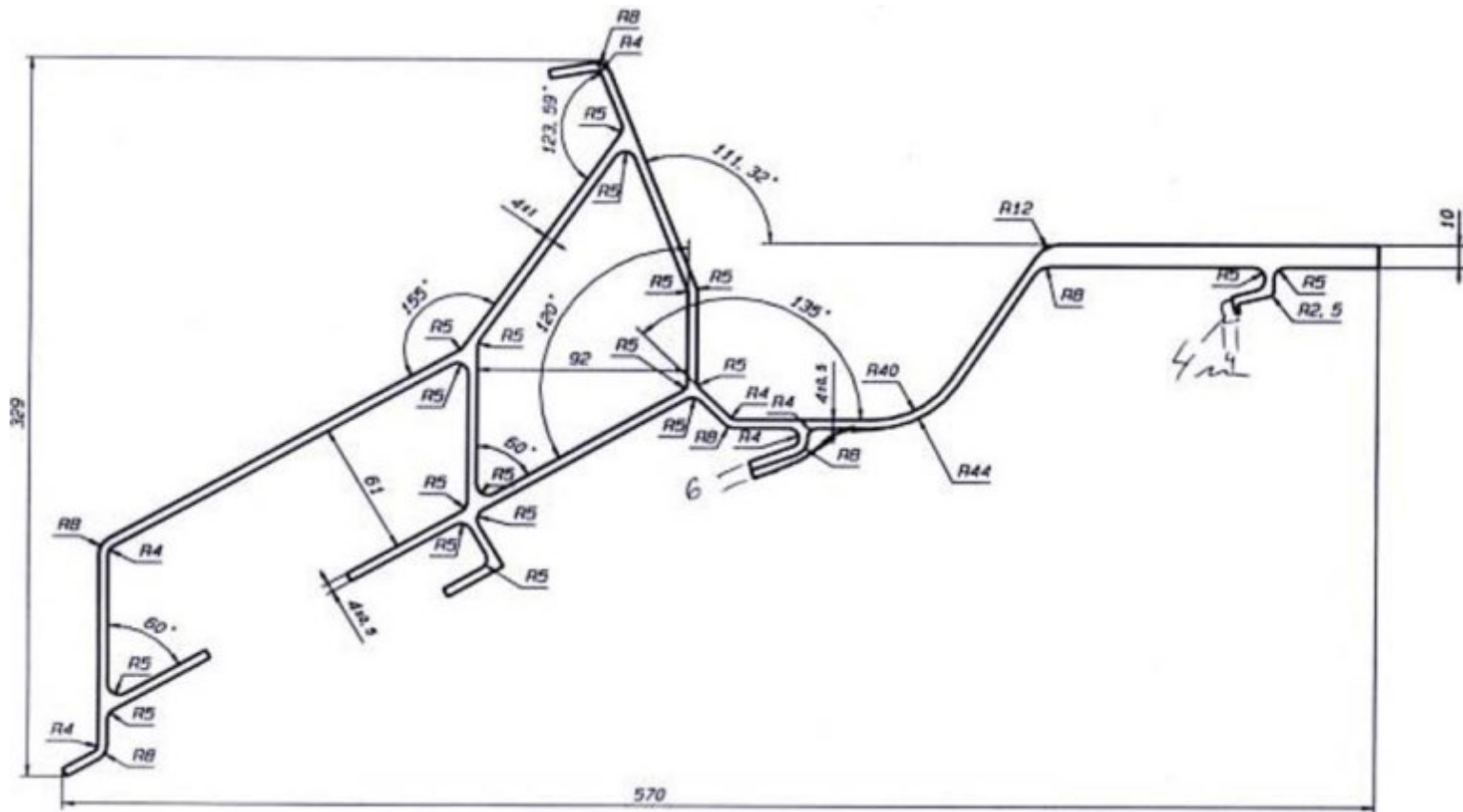


Source: Pultrex

Profiles - Shapes



- Almost any 2 dimensional shape possible:



Source: IHandbuch FVW

Profiles – Radius Shapes



- Profiles with constant radius
- Variable shapes



Source: Thomas Technik

Profiles – Radius Shapes



- Utilize the translucent material for optical effects
- In combination with the mechanical strength



Source: Thomas Technik

Market Share



■ Share of the pultrusion technology (GRP production Europe)

	2009 (kt)	2010 (kt)	2011 (kt)	2012 (kt)	2013* (kt)
SMC	160	198	198	188	184
BMC	56	69	69	70	71
Σ SMC/BMC	216	267	267	258	255
Hand lay-up	123	160	160	145	142
Spray-up	74	92	98	90	90
Σ Open mould	197	252	258	235	232
RTM	94	113	120	120	126
Sheets	56	72	77	78	84
Pultrusion	39	47	51	47	47
Σ Continuous processing	95	119	128	125	131
Filament winding	69	82	86	80	78
Centrifugal casting	55	66	69	67	66
Σ Pipes and Tanks	124	148	155	147	144
GMT/LFT	75	100	105	108	114
Others	14	16	16	17	18
Sum:	<u>815</u>	<u>1.015</u>	<u>1.049</u>	<u>1.010</u>	<u>1.020</u>

2013* = estimated

Applications



- Construction & Infrastructure
- Sports & Leisure, Household
- Electric & Electronic
- Energy, Oil & Gas, Chemical
- Transportation

Applications



- Construction & Infrastructure
- Sports & Leisure, Household
- Electric & Electronic
- Energy, Oil & Gas, Chemical
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Construction & Infrastructure



- Roof trusses
- A-frames



Source: Pultrex



Source: Pultrex

Construction & Infrastructure



- Space Frames
- Handrails



Source: ATP



Source: Pultrex

Construction & Infrastructure



- Bridges



Source: Pultrex

Construction & Infrastructure



- Fencing
- Handrails



Source: ATP



Source: Pultrex



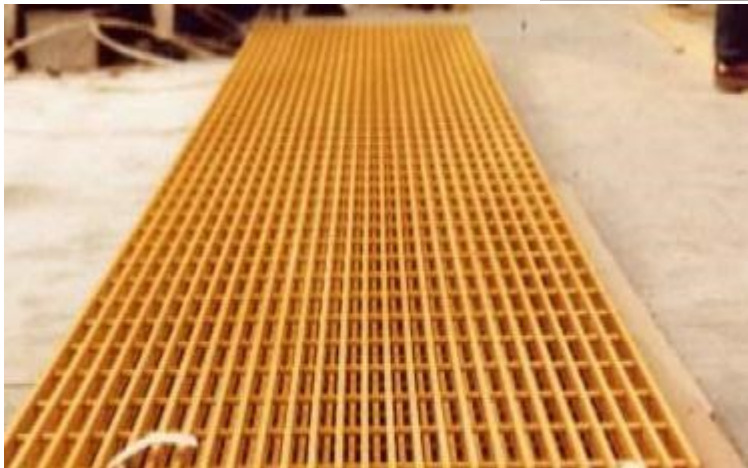
Source: Pultrex



- Gratings



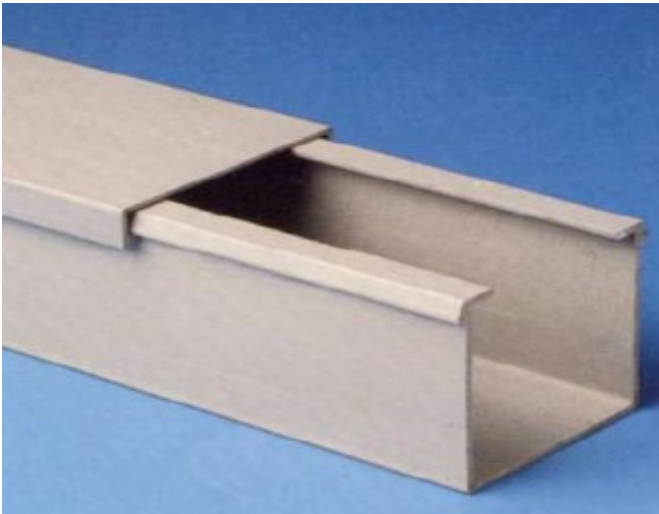
Source: Pultrex



Source: Pultrex



- Cable Trays



Source: Pultrex



Source: Röchling

Construction & Infrastructure



- Cable Trays in various locations



Source: Röchling



- Cable Trays in various shapes



Source: TC Domine



- Housing with seven doors



Source: TC Domine

Construction & Infrastructure



- Single storey building made with jute fibers



Source: Pultrex



- Rail joints



Source: Exel



- Anchoring bolts



Source: ATP

Applications



- Construction & Infrastructure
- Sports & Leisure, Household
- Electric & Electronic
- Energy, Oil & Gas, Chemical
- Transportation

Sports & Leisure, Household



- Sail battens
- Fishing rods



Source: EPTA Group



Source: EPTA Group

Sports & Leisure, Household



- Stadium seating



Source: Pultrex

Sports & Leisure, Household



- Tool handles



Source: Exel

Applications



- Construction & Infrastructure
- Sports & Leisure, Household
- **Electric & Electronic**
- Energy, Oil & Gas, Chemical
- Transportation



- Radio & telephone antennas



Source: Pultrex



- Foundation and spacers for current transformers



Source: Röchling



Source: Röchling



- Insulating and ignition proof ladder systems



Source: Pultrex



Source: Pultrex



Source: Pultrex

Applications



- Construction & Infrastructure
- Sports & Leisure, Household
- Electric & Electronic
- Energy, Oil & Gas, Chemical
- Transportation



- Structures for solar panels



Source: EPTA Group



- Wind turbine blades

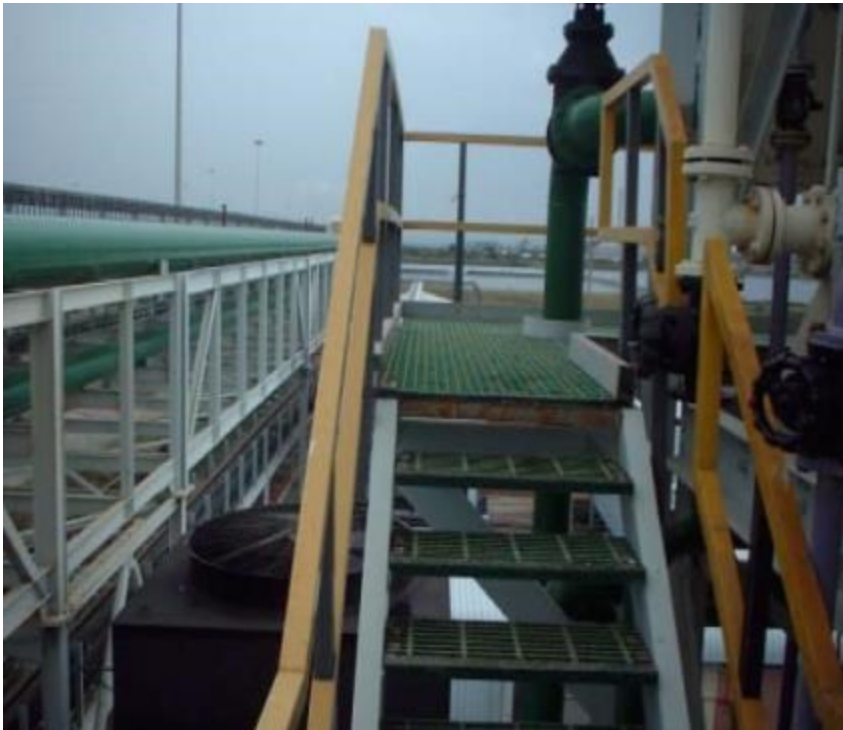


Source: Röchling

Energy, Oil & Gas, Chemical



- Gratings and handrails for chemical plant and oil platforms



Source: Pultrex



Source: Pultrex



- Gratings and handrails for cooling towers



Source: TC Domine

Energy, Oil & Gas, Chemical



- Stairways for water and sewage treatment plants



Source: TC Domine



Source: Alto



- Platforms for sewage treatment plants



Source: TC Domine

Energy, Oil & Gas, Chemical



- Bridges for sewage treatment plants
- Span length: 6m
- Incl. mounts for agitators



Source: TC Domine

Energy, Oil & Gas, Chemical



- Caged ladder systems for tanks
- Scaffolding towers
- Platform ladders



Source: Pultrex



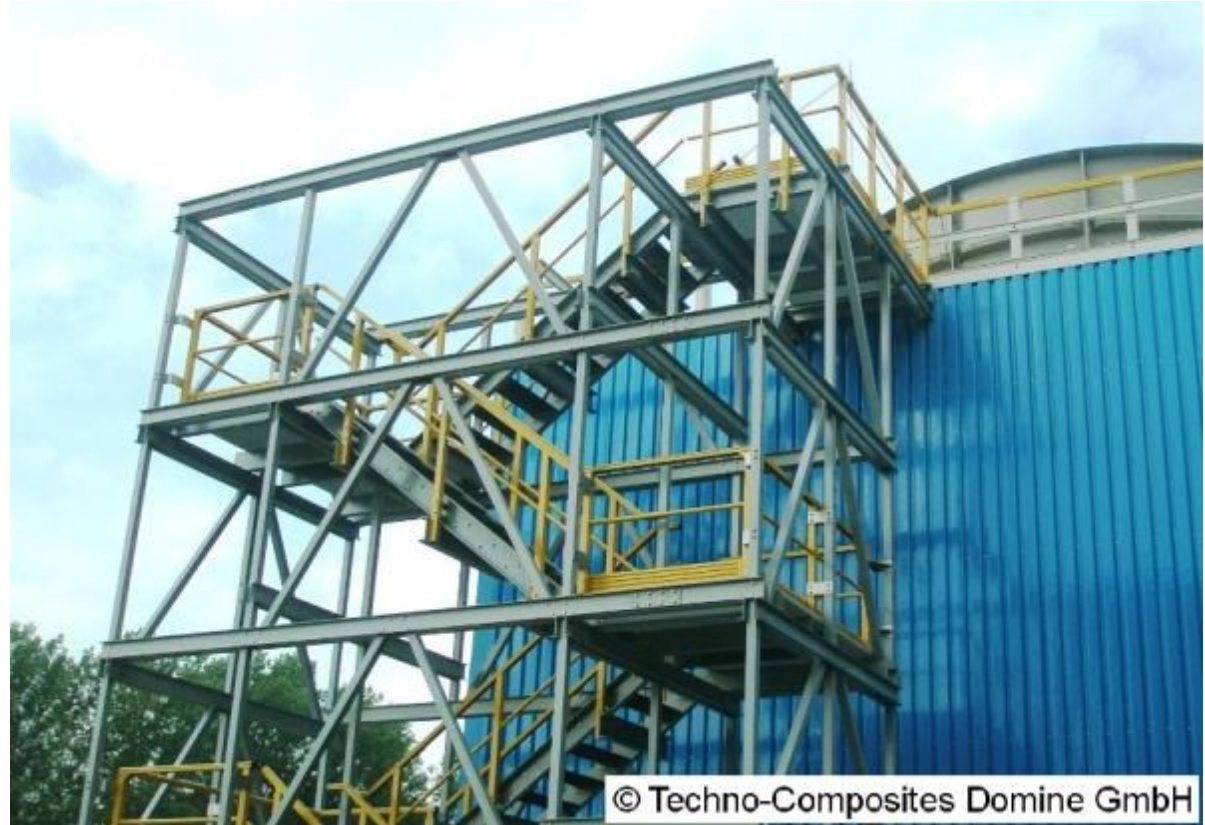
Source: Pultrex



Source: Pultrex



- Stair towers for cooling towers



Source: TC Domine



- Frameworks and handrails for tanks



Source: TC Domine

Applications



- Construction & Infrastructure
- Sports & Leisure, Household
- Electric & Electronic
- Energy, Oil & Gas, Chemical
- Transportation

Transportation



- External paneling for busses



Source: Röchling



Source: Röchling

Transportation



- Internal paneling for busses

© Techno-Composites Domine GmbH



Source: TC Domine

Transportation



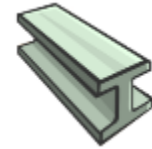
- Internal paneling for trains



Source: TC Domine

Source: TC Domine

Transportation



- Internal train panel in detail
- Pultruded, milled and drilled



© Techno-Composites Domine GmbH

Source: TC Domine

Transportation



- Internal train panel in detail
- Pultruded cut and milled



© Techno-Composites Domine GmbH

Source: TC Domine

Transportation



- Bus parts



Source: Pultrex

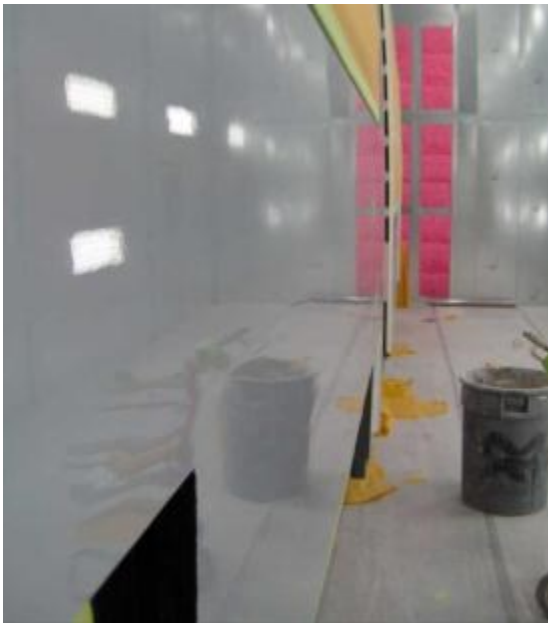


Source: Pultrex

Transportation



- External paneling for trains and trams
- Coated surfaces of excellent quality



Source: Röchling



Source: Röchling

Transportation



- Body panels for trams



Source: EPTA Group



- Springs



Source: Thomas Technik



Source: Thomas Technik

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Sustainability



- Pultrusion is one of the most energy efficient processes

