Engineering in GRP pipes and tanks

Fundamentals, behaviour and design philosophy

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LinkedIn

What we will cover today

- Why GRP behaves differently (block 1)
- Why systems fail (block 2)
- **Building blocks (block 3)**
- Behaviour and design (block 4)
- Standards (ISO 14692 / EN 13121) (block 5)
- Inspection and failure detection (block 6)

What defines GRP behaviour

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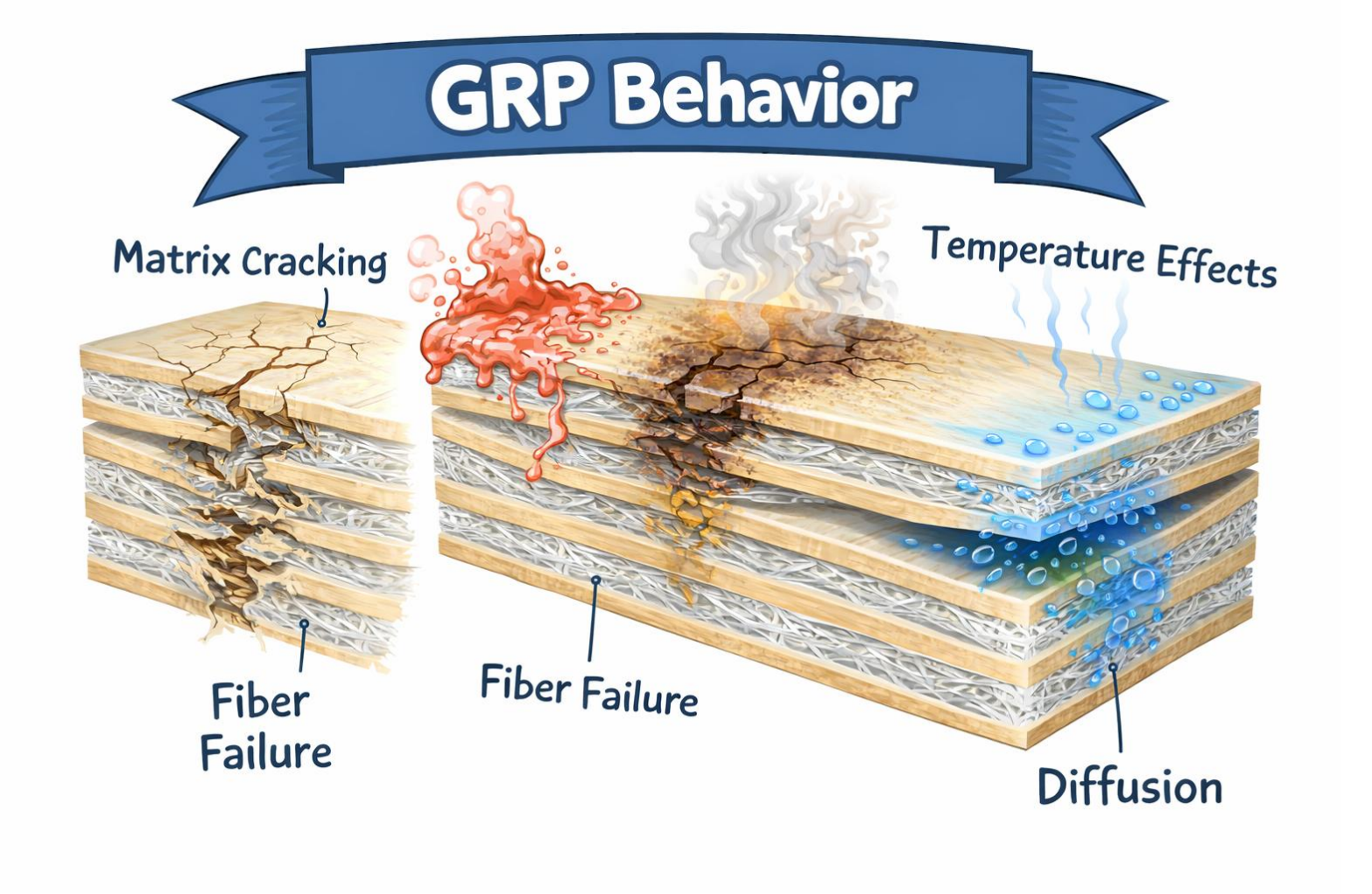
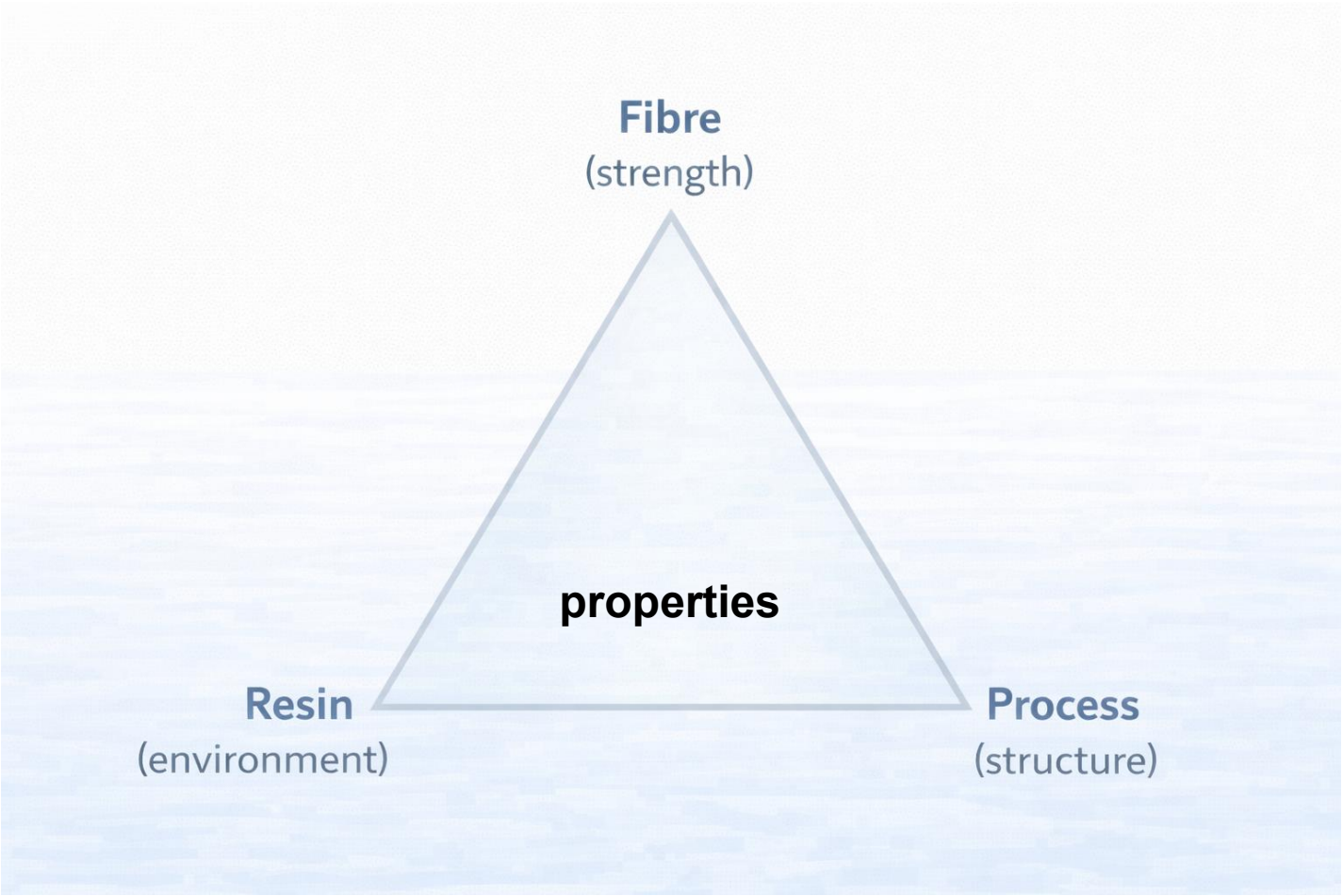


"Now we understand where failures occur.
Let's understand why."

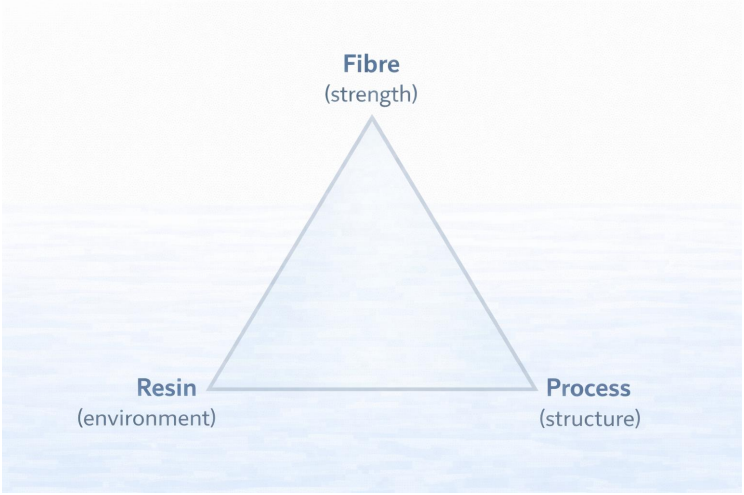
GRP is an engineered material



“Properties are designed — not given”

“Unlike steel, GRP is not one material — it is a combination we create.”

GRP does not exist



- Different fiber orientation
- Different process

“Every GRP is different — depending on how it is made and what it is made of.”

What carries the load

Fibre = strength and stiffness

- Carries load
- Determines stiffness
- Direction-dependent

Direction matters

- Hoop → pressure
- Axial → bending / temperature

“Direction defines strength — this is fundamental.”

(Use existing visuals)

Fibre contribution factors

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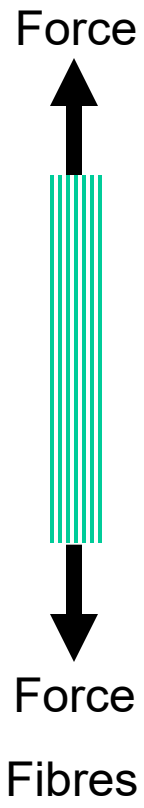
1. Basic mechanical properties of the fiber
2. Surface interaction of the fiber and the matrix (interface)
3. Amount of fibers in the composite (Fiber fraction)
4. Orientation of the fibers in the composite

GRP Components; glass and carbon

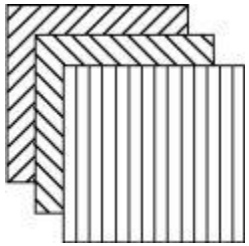


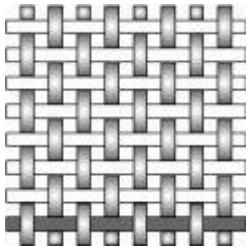
	Tensile Strength MPa	Elongation at break %	Tensile modules GPa
Glass fibres (E-)	1500	4.8	72
Carbon fibres (Toray)	6900	2.4	290

Glass type	Chemical characterisation
E	Alumina-borosilicate glass, ≤ 1 % alkali content
E-CR	Alumina-limesilicate glass, ≤ 1 % alkali content
AR	Zirconium-lime glass, ≈ 15 % zirconium content
A	Alkali-lime glass ≈ 15 % Alkali content
C	Alkali-lime glass, ≈ 8 % Alkali content

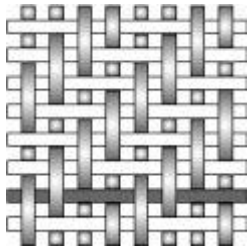
Reinforcement

- Continuous roving
  - Direct, flat
  - Assembled, round
- Chopped strand mats
- Continuous strand mats
- Woven fabrics
  - Unidirectional
  - Bi-directional
  - Multi-axial
- Knitted





Plain weave



twill weave

Reinforcement

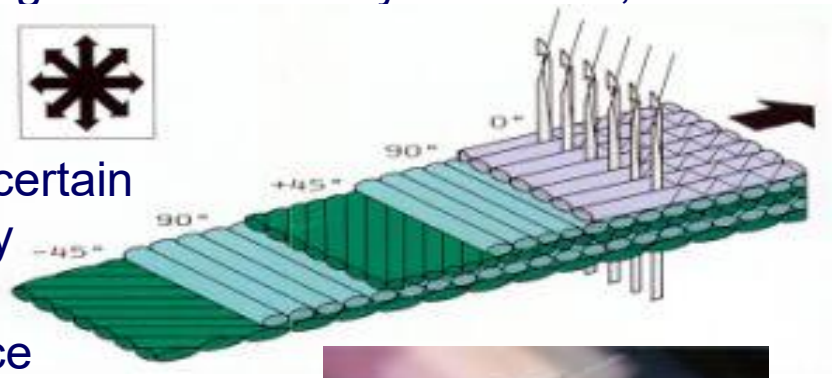
- Glasmats
  - Hand lay up mats: chopped fibers with a binder based on resin. This binder determines the processing properties:
    - Emulsion bound mats: feels soft, binder slowly dissolves. Easy plyable, not suitable for transparent laminates. Not suitable for all resins
    - Powderbound mats: binder dissolves quickly into styrene. Often irritates to the skin. Suitable for chemical resistance, boats, pools, etc.
    - Press or injection mats
    - Heavy bound mat or insoluble binders.

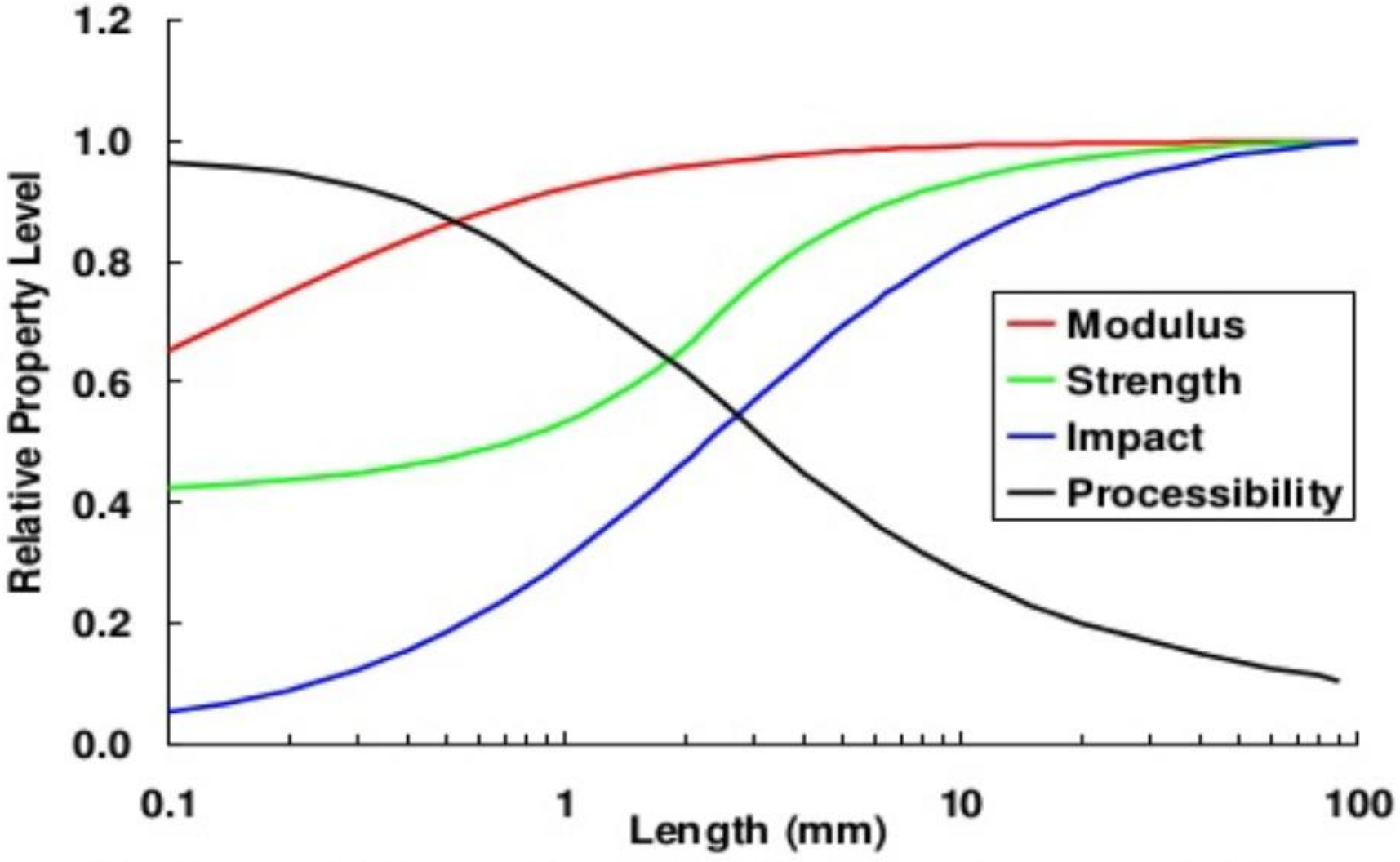
Combinations are almost endless




Reinforcements

- Mechanical bound mat
  - No binder. Loose fibers are stitched on a surface, often a (glass- or synthetic) fleece or veil. Many combinations, options and variations.
- Continuous mats
  - Consist of continuous rovings, frequently used with injection or press moulding. Not suitable for hand laminating. Also here many variations, also in tex value
- Multi axial fabrics
  - Rovings are not woven but are laid in a certain direction on top of each other and mostly connected by stitching. Fabrics will be impregnated more homogeneously hence reduced stresses in the laminate
- Uni directional fabricsweefsels
  - Large number of rovings in warp- and only limited in weft direction. Purpose is to gain maximum strength in 1 direction.

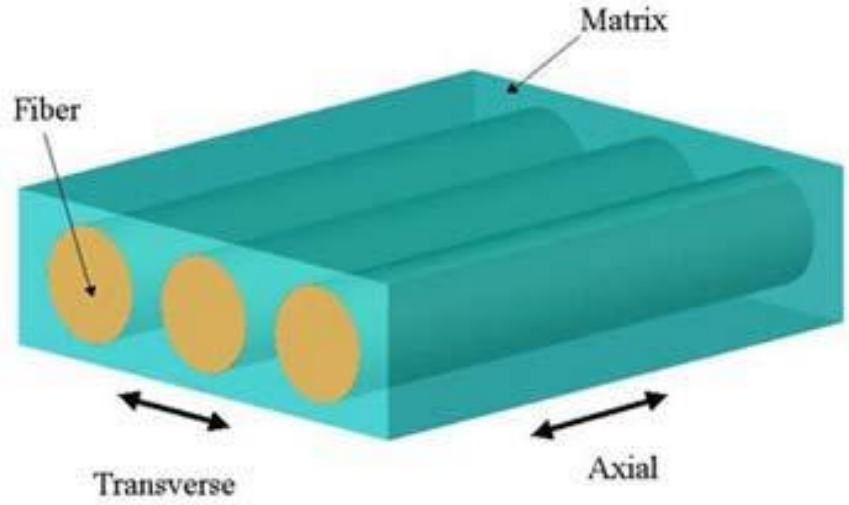


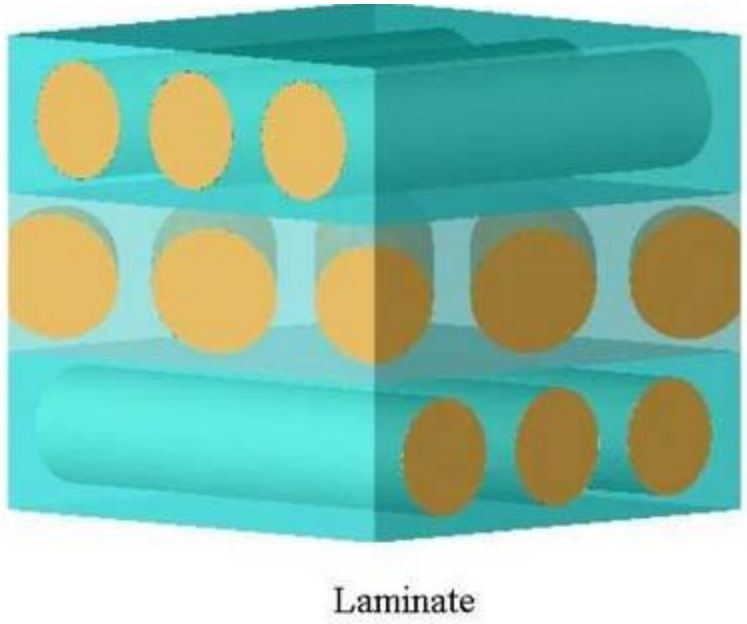

1.2
1.0
0.8
0.6
0.4
0.2
0.0
Relative Property Level
0.1
1
10
100
Length (mm)
Modulus
Strength
Impact
Processibility

Glass treatment, essential for quality Composite

- Sizings and binders
- Sizing
  - Coupling agent between glass and resin
  - Protection against process damage
  - (either due to production or weaving)
- Binder
  - ‘glues’ fibers together
  - Dissolves in styrene
    - Powder based (melted)
    - emulsified

How do these materials together define the Mechanical properties





Impact of sizings and binders of glass fiber on mechanical properties.

Resin = constant

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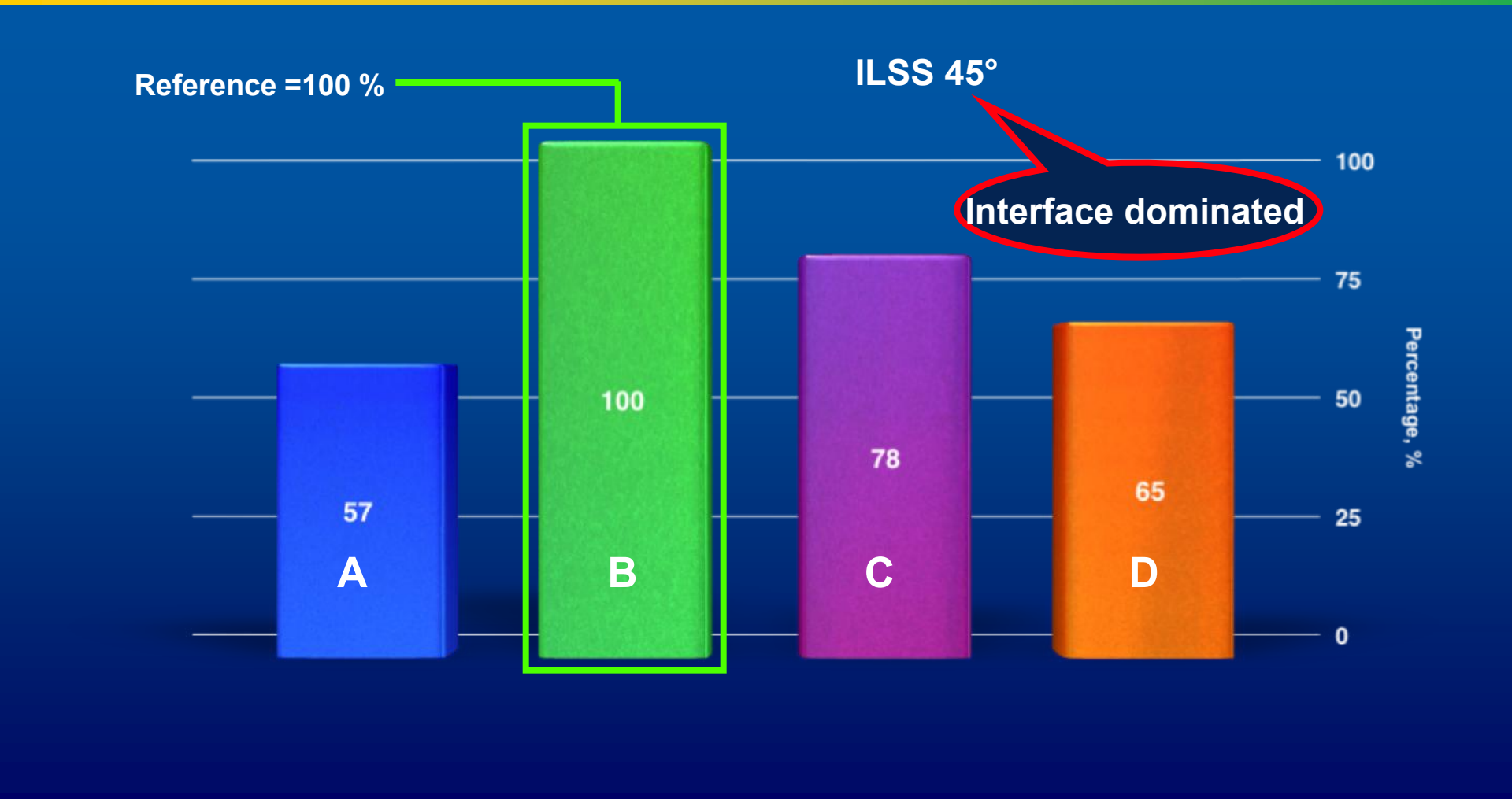
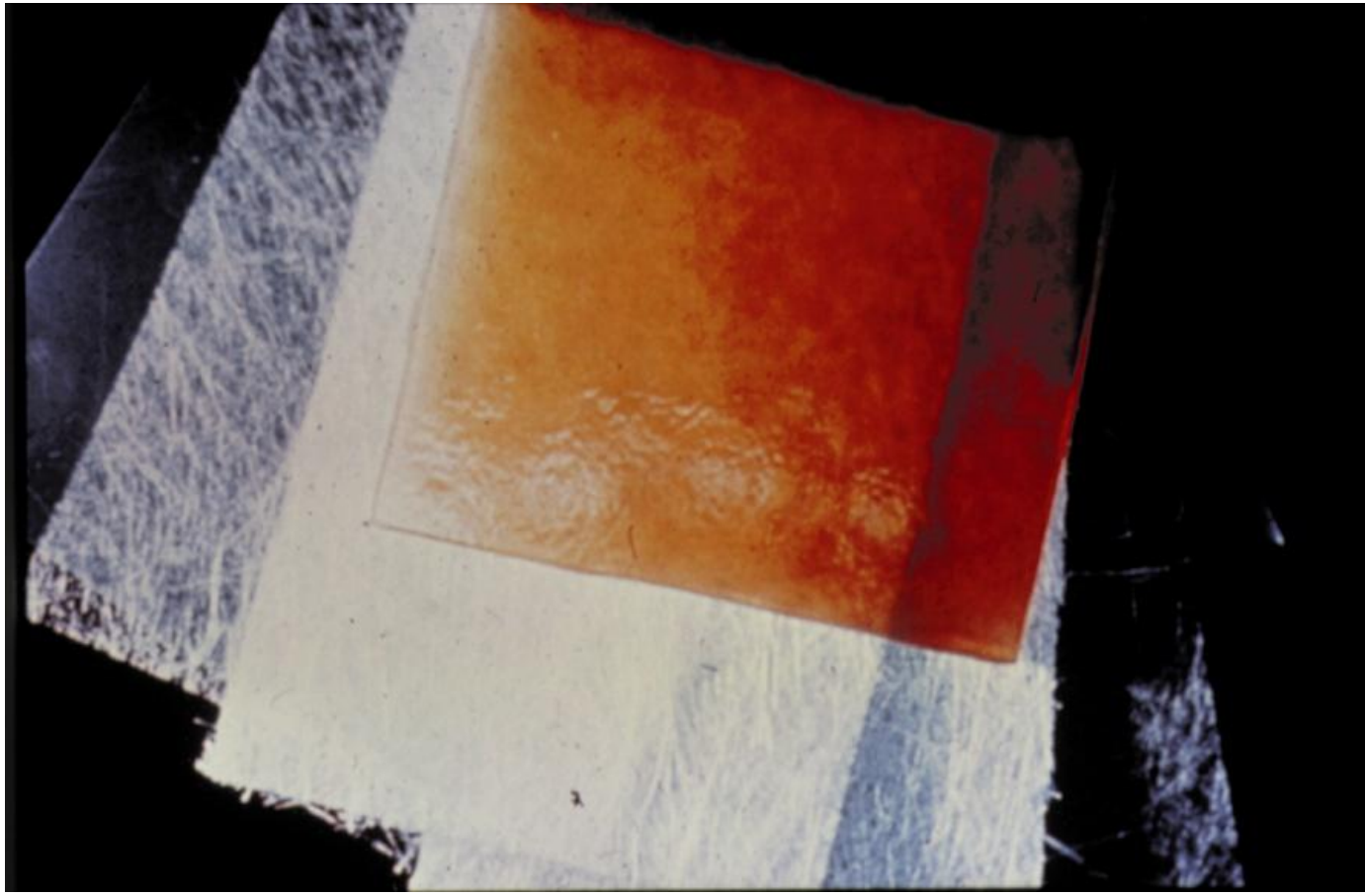


Source: AOC composite resins

PART 2 — RESIN

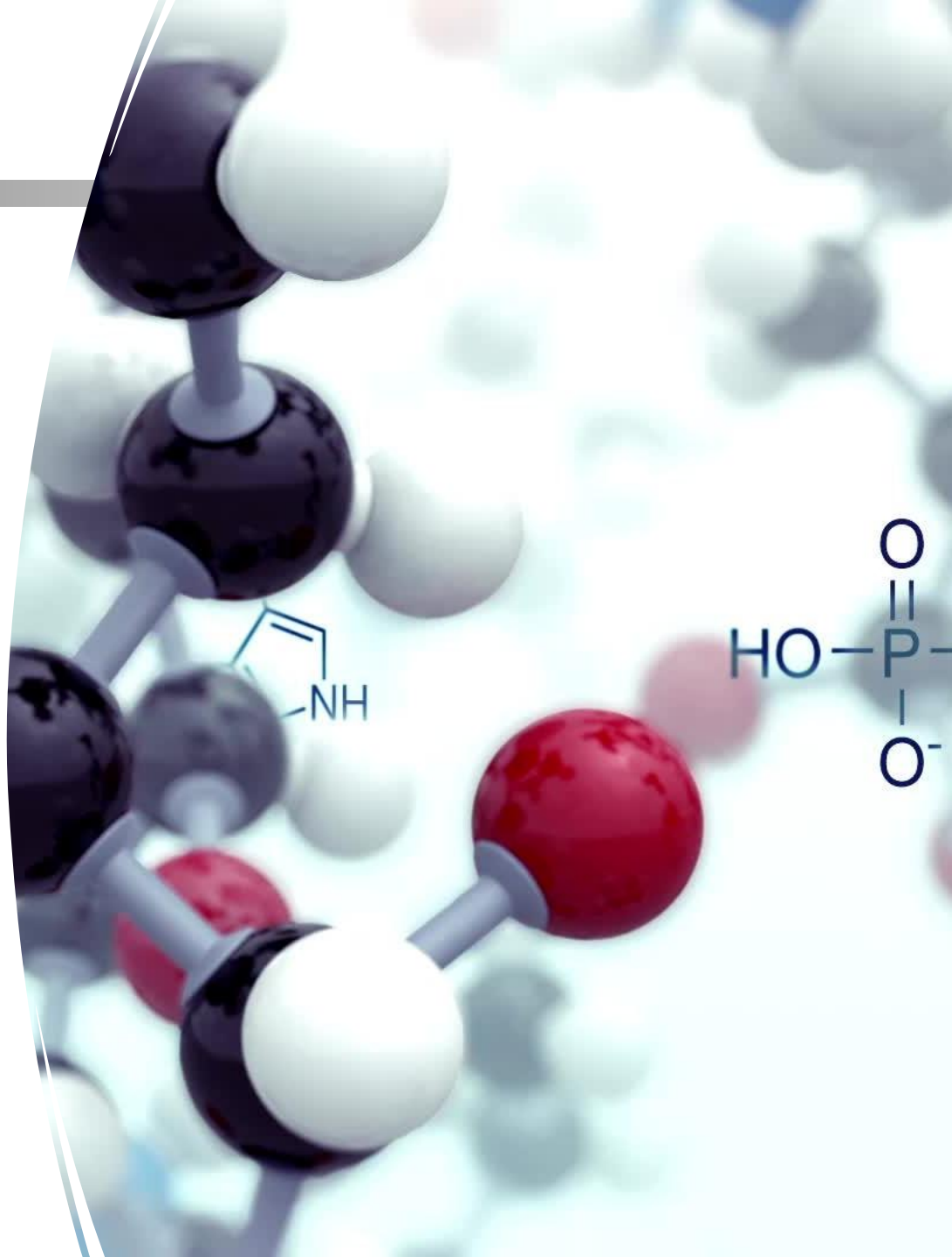
- Protects fibres
- Transfers load
- Defines chemical resistance



“Resin connects the fibres—and protects them.”

Plastics

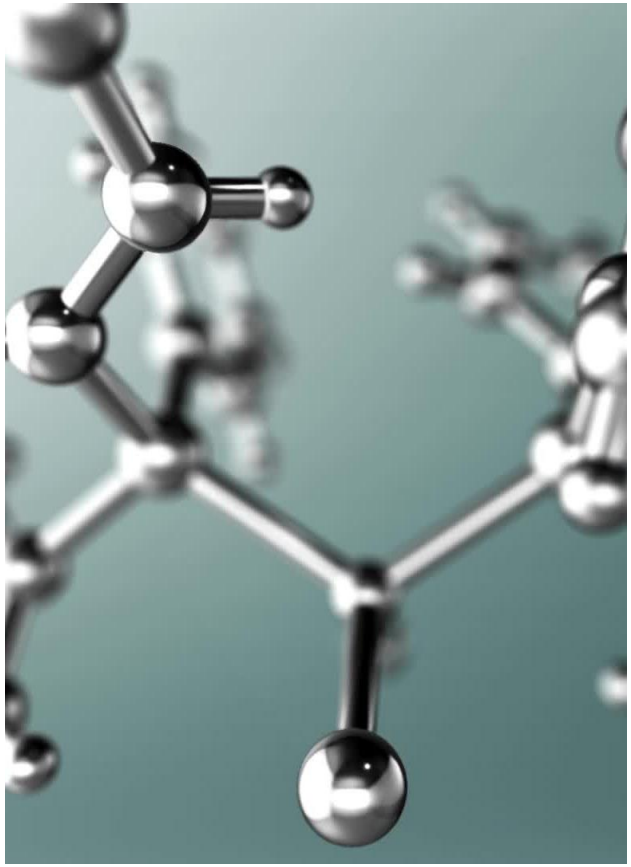
- Polymerization of simple organic substances
- Forming very long chains
  - Branched or non-branched
  - Length up to 1,000,000 times the molecule of for ex. Water or salt.
- Wide variety of properties
  - Soft-hard
  - Robust – fragile
  - Elastic-rigid
  - Etc..
- Wide variety of applications



Plastics

- Three main groups:
  - Thermosets
  - Thermoplastics
  - Elastomers

- Distinction based on:
  - Chemical reaction between the chains
    - Connection as strong as the chain
    - 3-d structure
  - physical attraction between the chains
    - Attraction can temporarily be eliminated
    - Mechanical entwining between the long molecules
    - Molecular/binding force between mutual molecules



Thermosets

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Form permanent large 3D molecules

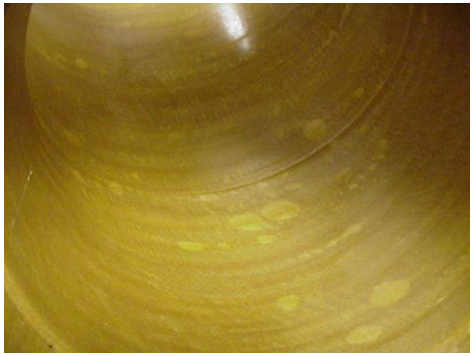
Construction industry requirement	Ph	Fu	EP	UP	VE
Processability	-	-	+	+++	+++
Mechanical stability	o	o	+++	+	++
Thermostability	+++	++	++	+	++
Chemical resistance					
Acids	?	o	+	+	+++
Alkalines	?	+	+	o	++
Solvents	?	++	+++	-	+

Note:

Ph: Phenolics
Fu: Furanes
EP: Epoxies
UP: Unsaturated polyesters
VE: Vinyl esters

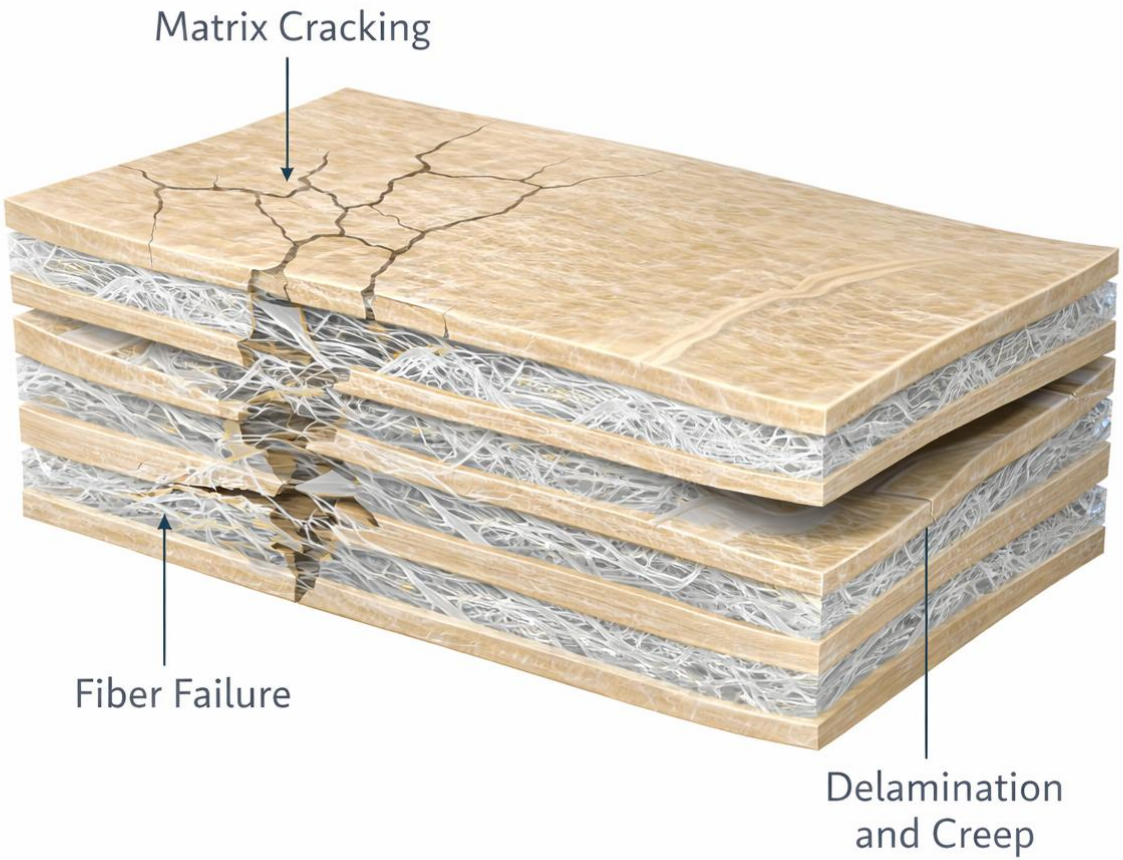
- = Poor
o = Fair
+ = Good
++ = Very good
+++ = Excellent
? = Not Known

Different resins → different performance



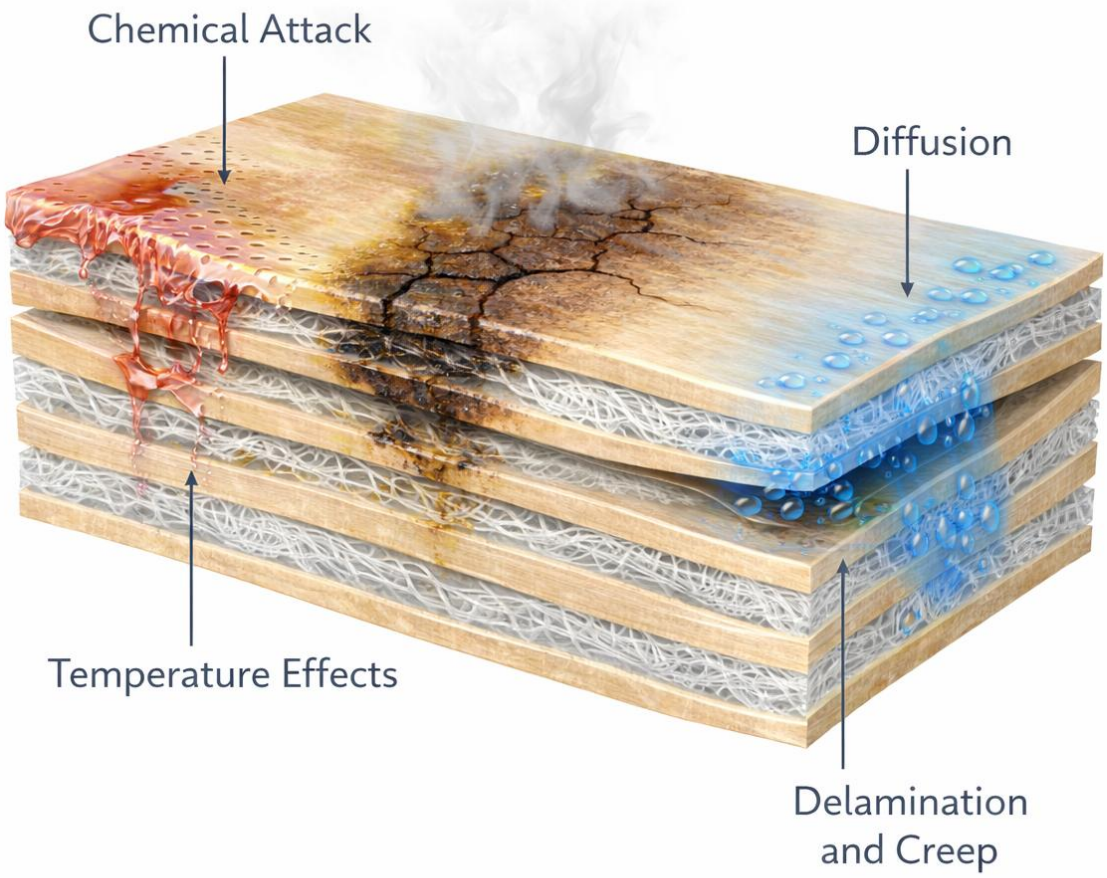
Resin	Typical use
Polyester	general use
Vinyl ester	chemical resistance
Epoxy	high performance

How GRP fails



“Failure is progressive—rarely sudden.”

Chemical behaviour



“GRP performance depends on environment.”

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The Ester Linkage

Weakest point

Hydrolysis

Chemical resistance

- **Corrosion testing**

- **According to ASTM C 581 and DIN 53393 (prEN 977 - EN 13121-2)**

Chemical resistance

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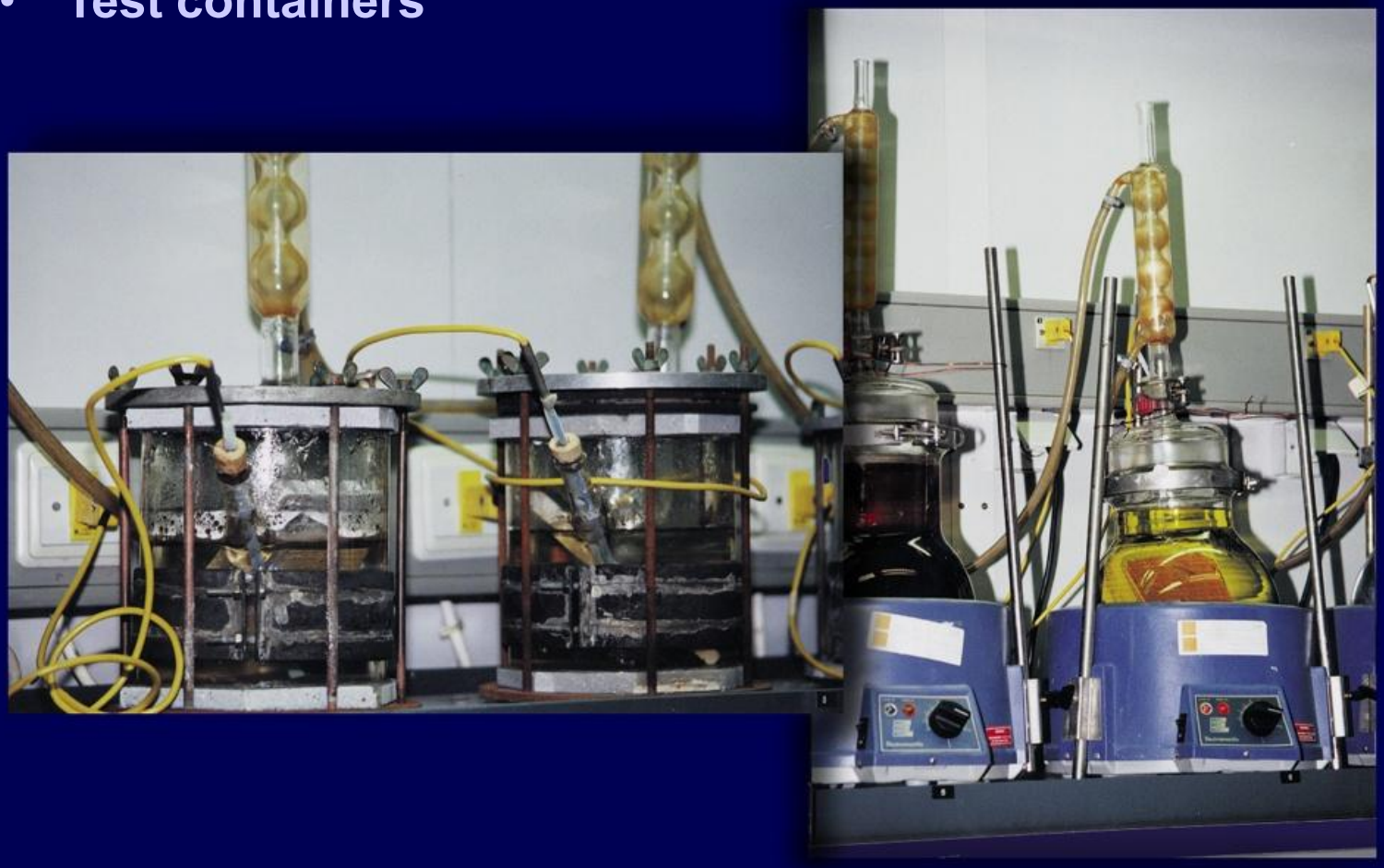
- Test containers



Chemical resistance

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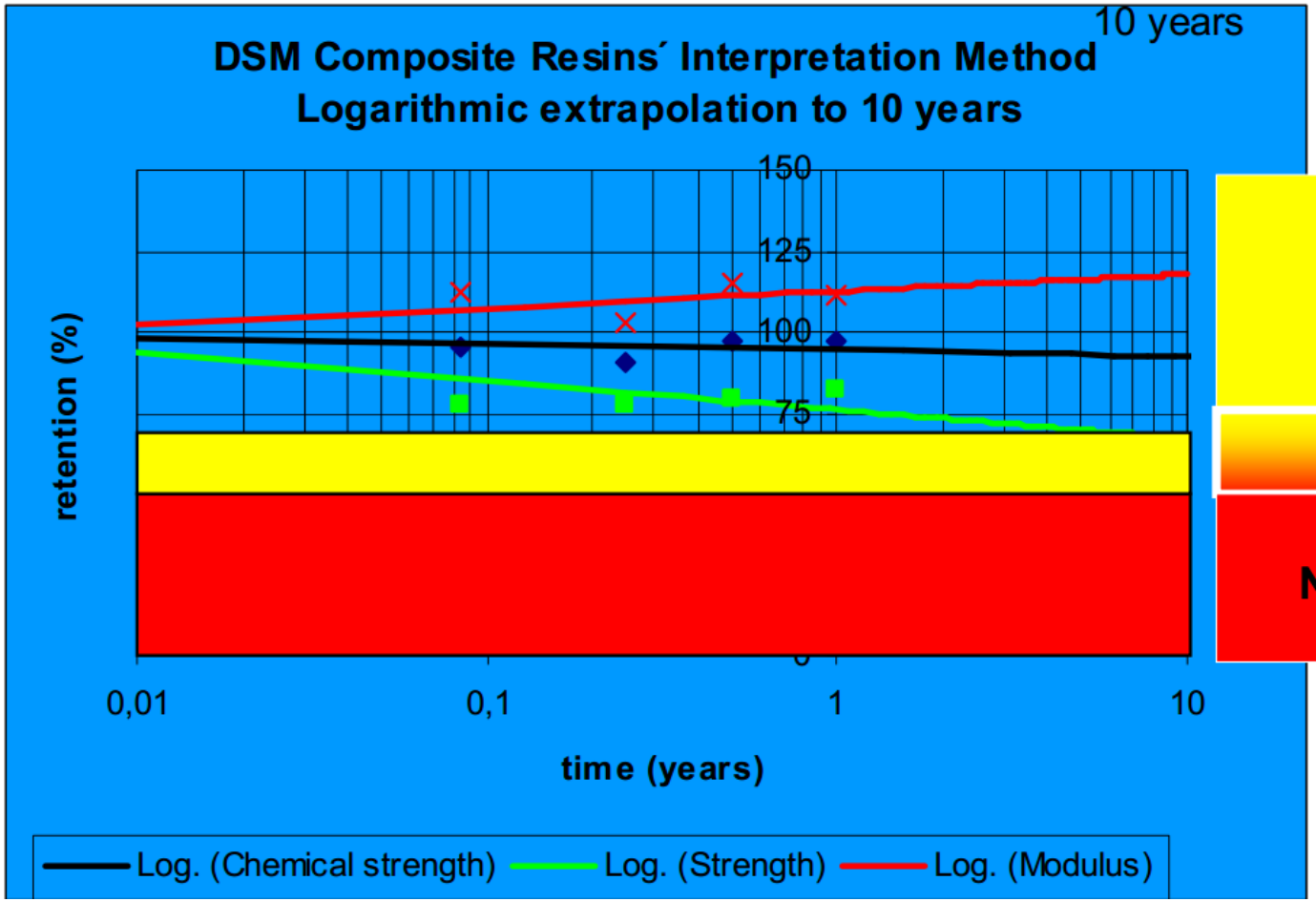
Test Criteria:

Double sided exposure with laminates (3.5 mm thick) – representing standard CBL



Chemical Resistant

Critical

Not Resistant

PART 3 — PROCESS

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It matters how it is made

Processing techniques

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Technique	*Process*
Open Mould	Hand Lay up Spray up Filament winding Chop Hoop winding, (dis)continuous
Closed mould	Centrifugal casting Pulltrusion Cold press Resin injection; RTM; S-RIM, VARI Hot press; SMC/BMC

Process defines structure: How you make it = what you get

Hand Lay Up

- Single sided mould
- Glass content around 35%
- Laminate thickness 2 - 25 mm
- No size limitations
- Low investment cost
- Low mould costs
- Styrene emission
- Labour intensive
- Low reproducability

Open Mould production techniques
Hand Lay Up; Spray Up

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properties

- single sided mould
- Glass content around 35%
- laminate thickness 2 - 25 mm
- no size limitations
- series around 100 - 5000 items per year

(Dis-) advantages:

- low investments
- low mould costs
- styrene emission
- labour intensive
- low reproducability

Spray up

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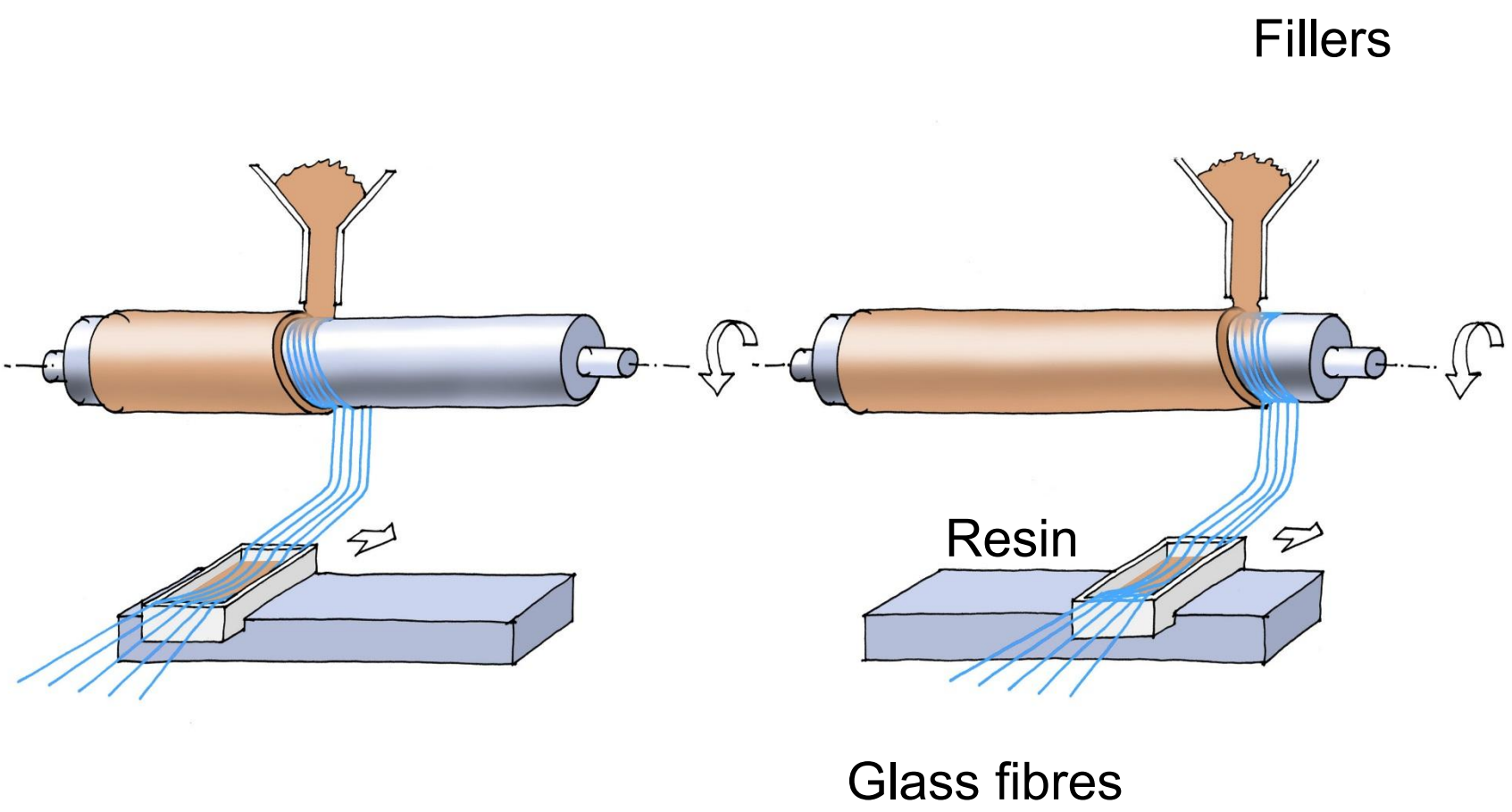
Helical filament winding



Filament winding

- Glass rovings used for uni-directional reinforcement in filament winding

Filament winding of pipes

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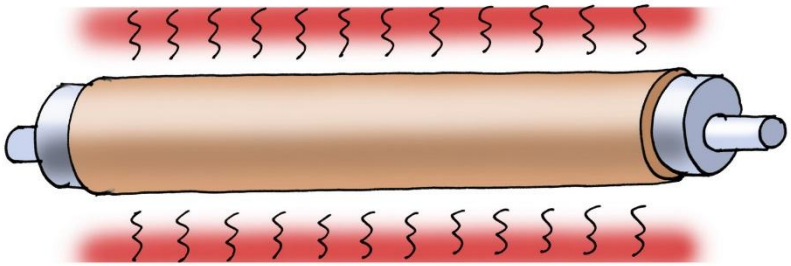
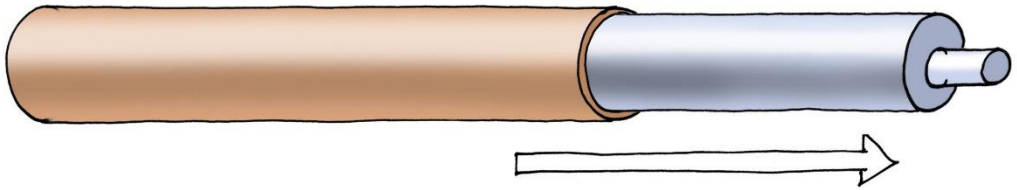
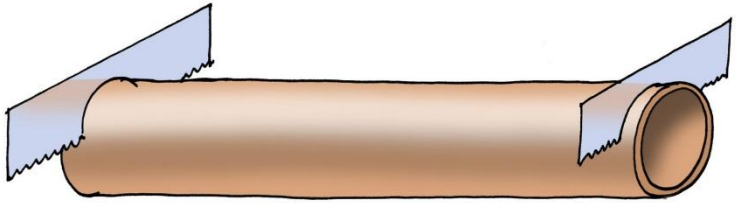
Precure



Mandrel Extraction



Saw Bench



Helical winding of pipes and tanks

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Filament winding

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- On-Site Filament Winding production of a storage tank

Helical winding producers

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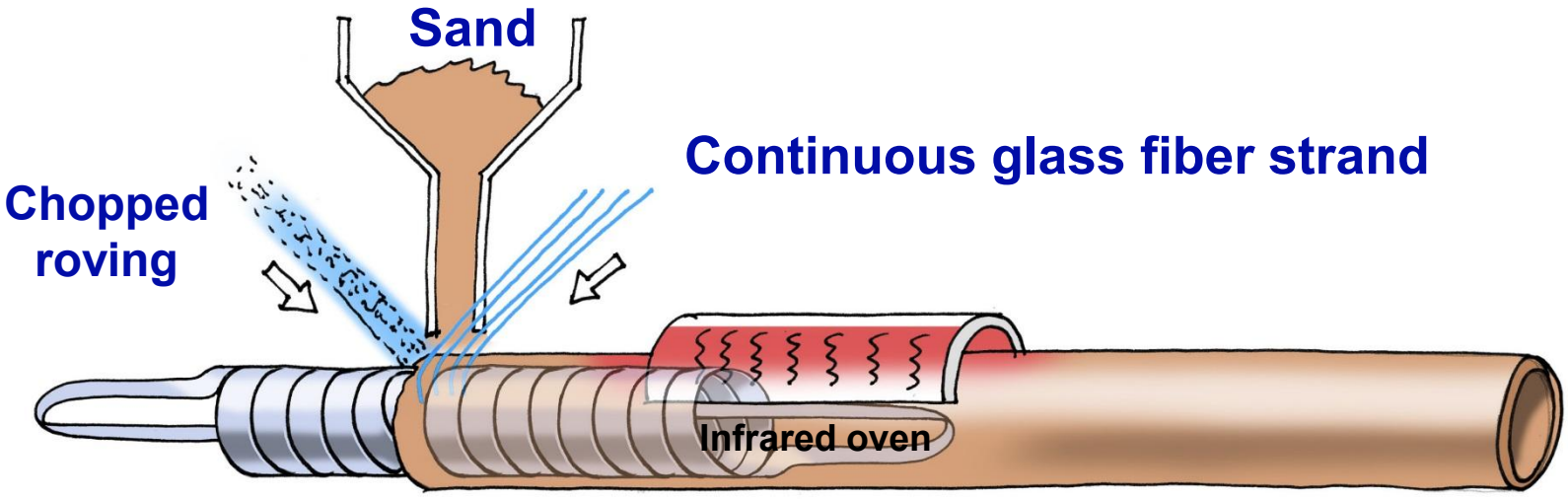
Pipe:

- Amitech (Sarplast)
- Future Pipe Industries (NL, UAE)
- Ameron (NL,FE)
- Fibredur Vanck (Ger)
- Protesa (Spa)
- Fibersol
- Selip
- …

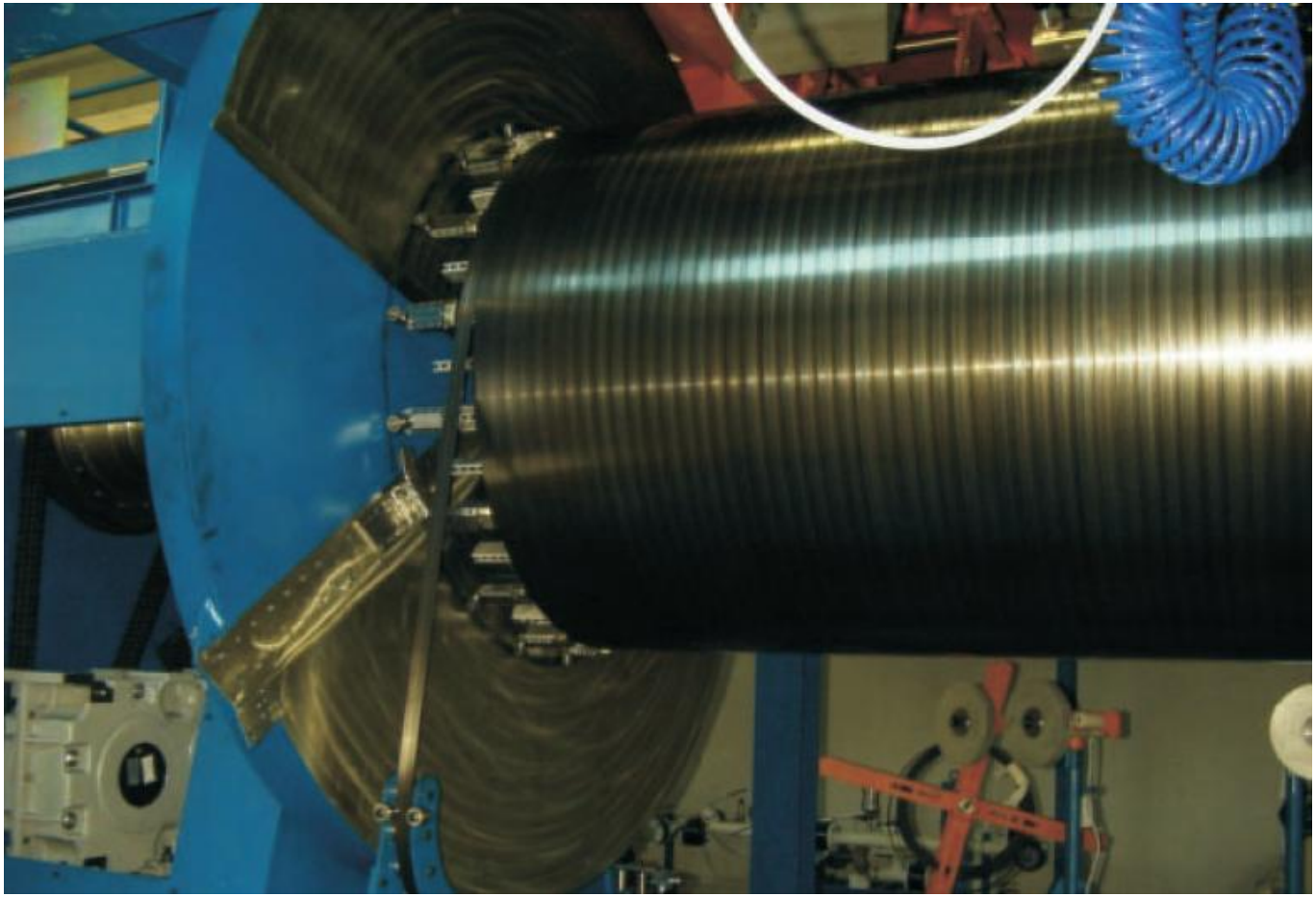
- **Tanks:**
- Plasticon (NL, Fr, PL, UK)
- Christen&Loudon (Ger)
- Kurotech
- ACS (Be)
- Selip
- …

Continuous filament winding



Diameters from 100 through 4000mm

How mold is produced cont. fill.



Continuous filament winding

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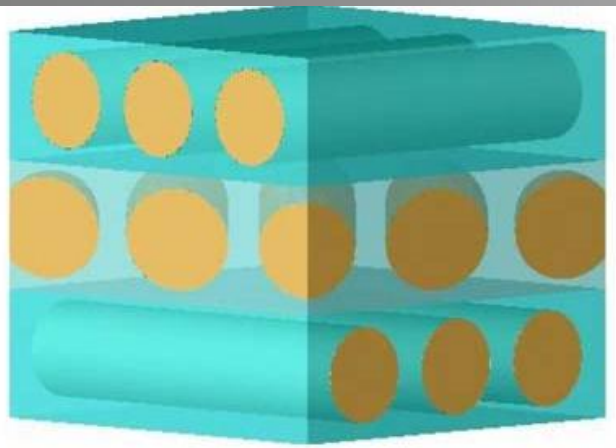
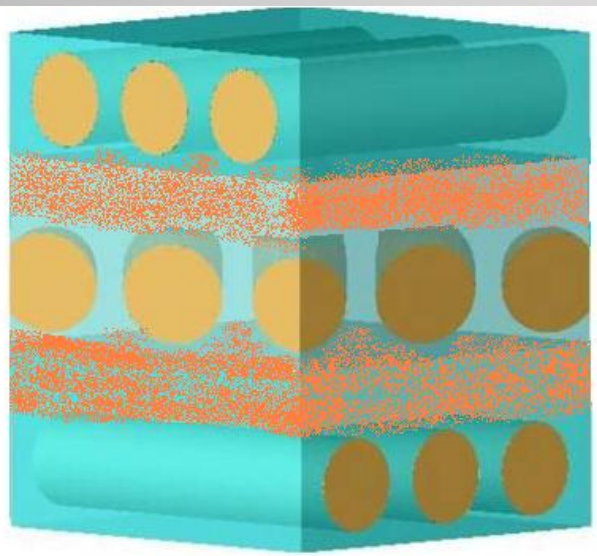
Continuous filament winding

Sand filling; replace glass



Laminate



- 3 winding layers: 1.8 mm
- Load bearing capacity = F (N)
- Higher allowable stress
- Higher E-modules
- PS: 1/12 * E * te^3: lower stiffness

- 3 winding layers: 3 mm
- Load bearing capacity = F (N) (constant)
- Lower allowable stress
- Lower E-module
- PS: 1/12 * E * te^3: lower stiffness
- Sand replaces glass, not resin

Filament wound pipe producers

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- Flowtite/Amiantit (No, Dl, Spa, Turkey
- FPI (ME)
- VED
- …

Spray Winding chop hoop

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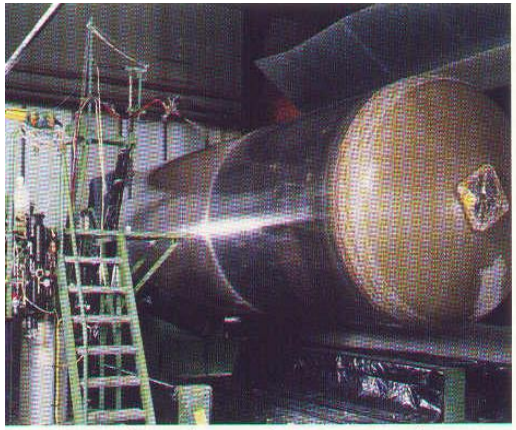
Properties:

- Combination Spray Up and Filament Winding
- fiber content ca. 35%
- suitable for cilindrical parts, for example storage silo's
- at this moment up to Ø 8 m

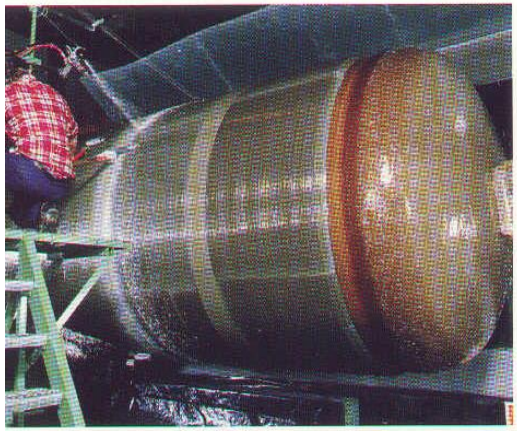
(dis)advantages:

- Large sizes possible
- Low investment
- Possibility of sandwich constructions
- high styrene emission



lanufacturing of an underground petrol storage tank
Application of the corrosion resistant liner resin

2 Application of the inner structural laminate



Application of the outer structural laminate on the foam core

4 Laminating the manhole

Typical filament wounded Applications

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Filament Hoop winding

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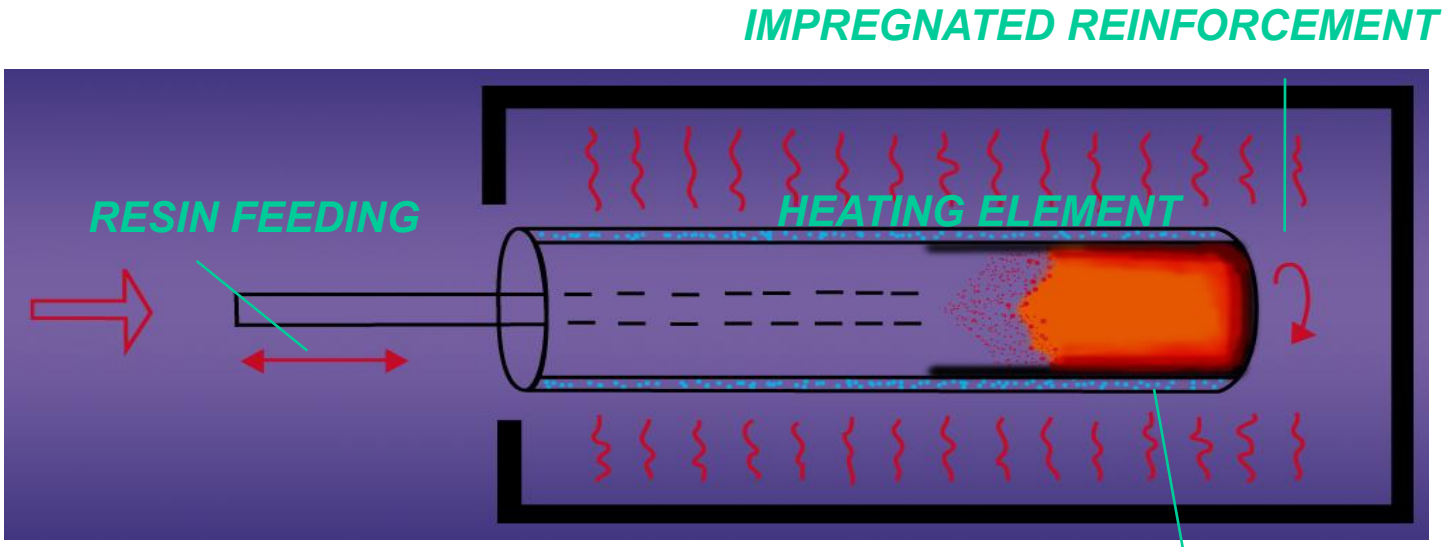
- **Fibre direction**

Centrifugal Casting

- **Fixed outside diameter**



High filler content/ high density/ lower material cost/ low properties
• Smooth outer surface

Centrifugal casting

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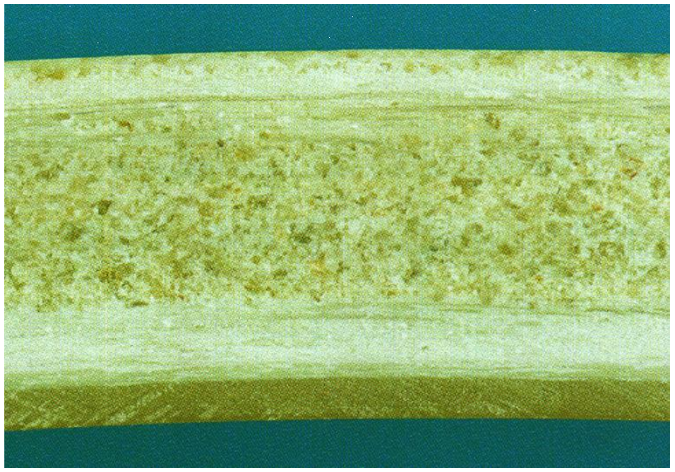
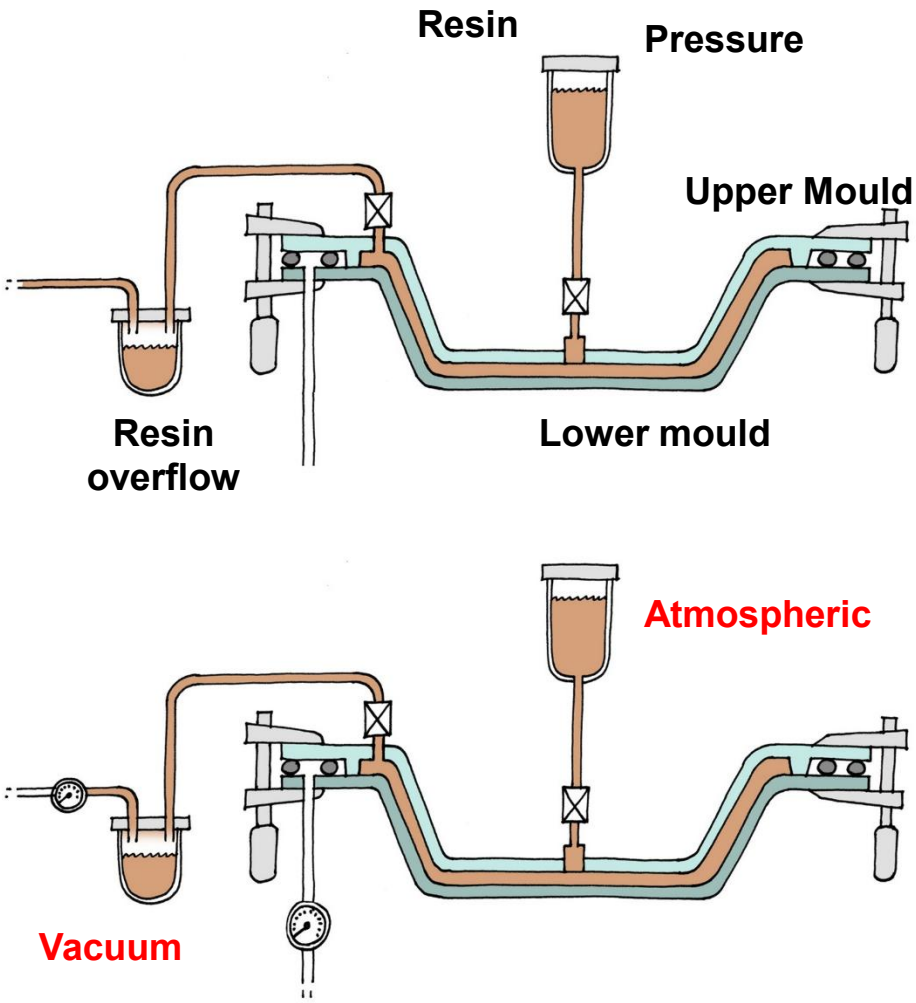


Closed mould techniques

Properties:
- Double sided mould
- Pre-cut glass fiber reinforcement
- Fiber content 35 - 60 %

(dis) Advantages
- Fast curing
- two-sided smooth surfaces
- No styrene emission
- rib stiffeners difficult

Examples: RTM, Vacuum injection



Press moulding

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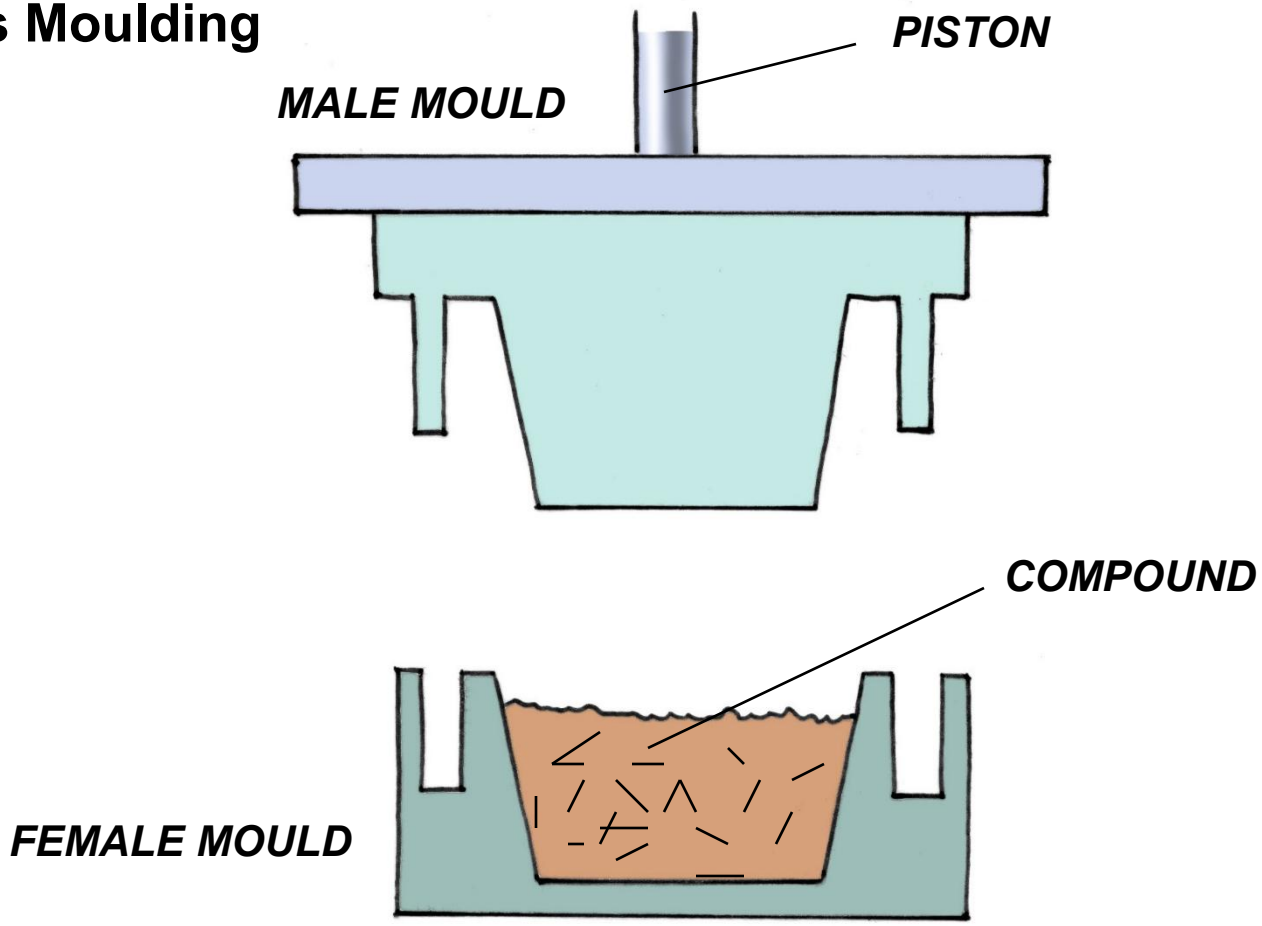
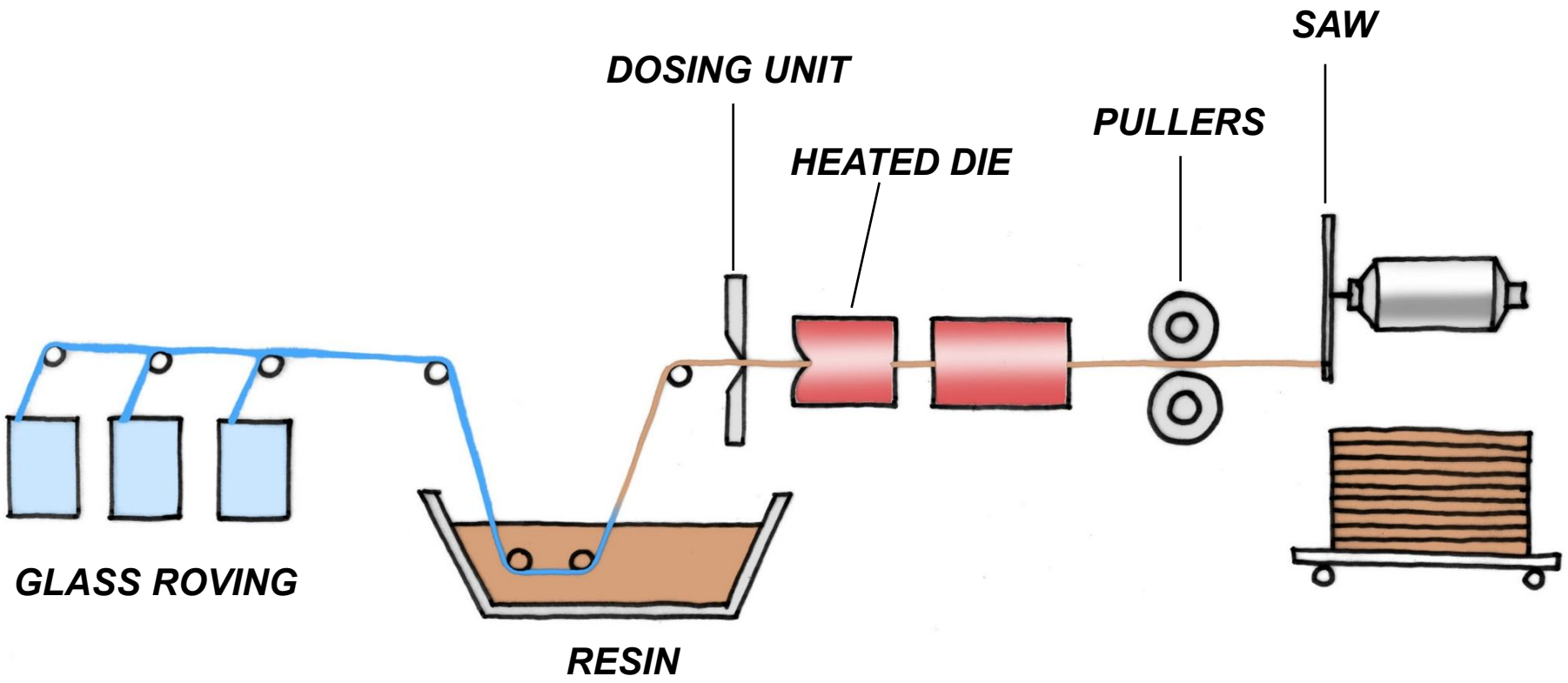
Hot/Cold Press Moulding *(bmc)*



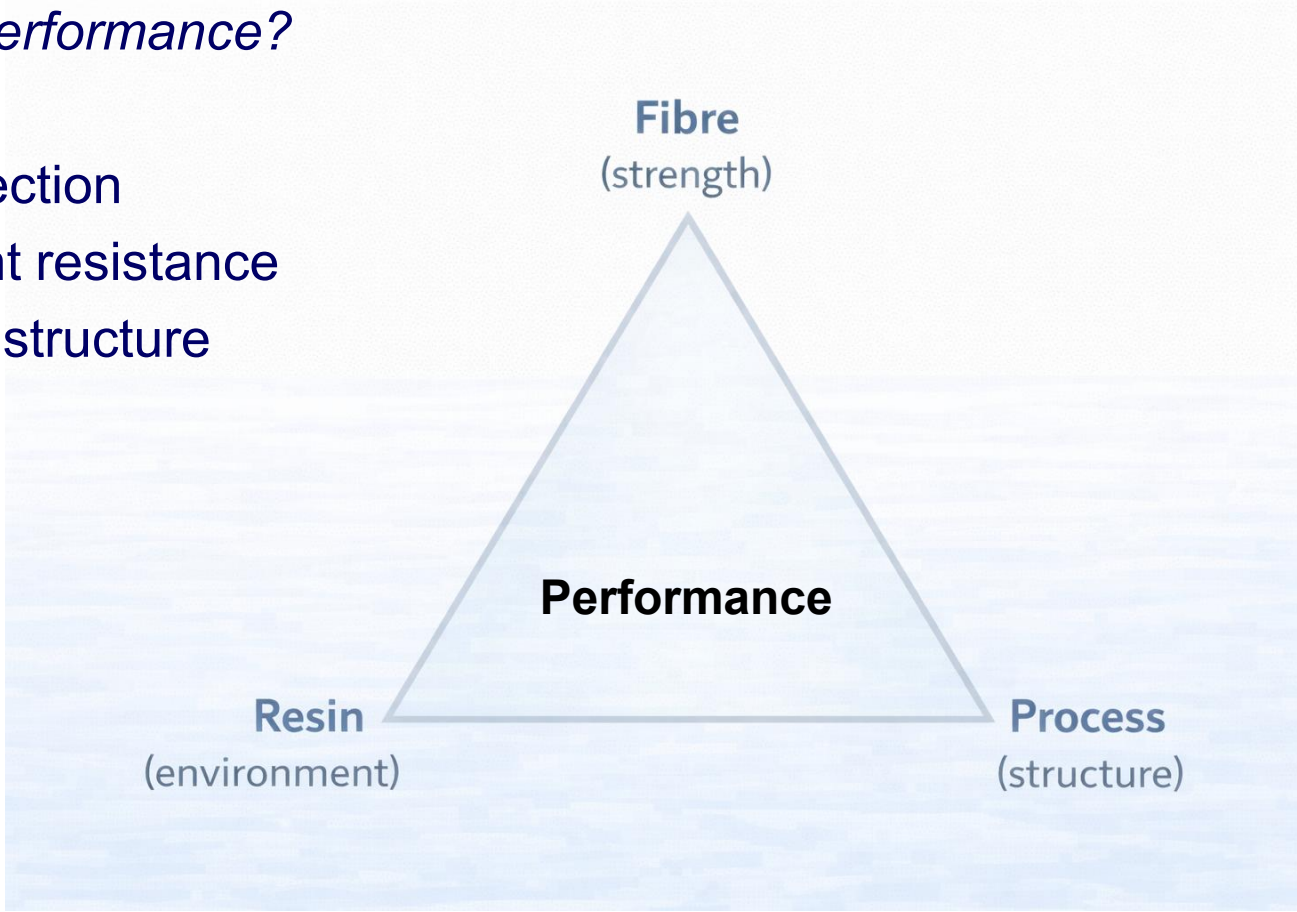
Pultrusion technique



Combine everything

- *What defines GRP performance?*

- Fibre → strength direction
- Resin → environment resistance
- Process → quality & structure



"You cannot change one without affecting the others. This is not a material — it's a system."

Same material — different behaviour

Example:

- Same resin
- Same fiber material

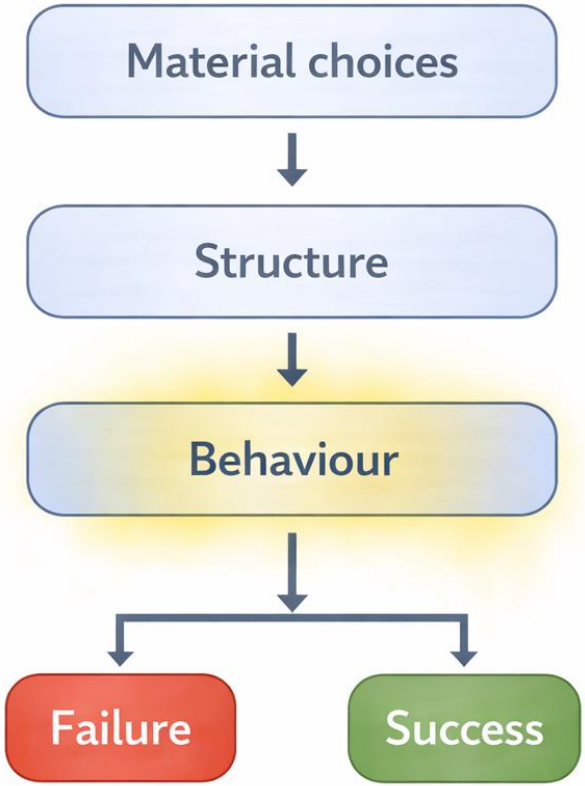
BUT:

- Different winding angle
- Different type
  → completely different performance

“This is why standards like ISO 14692 focus on performance — not just materials.”

Final message

- GRP is engineered
- Properties are not fixed
- Small changes → big effects



You don’t select GRP — you define it.”

“Everything we do — material, process, design — ends up here: behaviour.”

Agenda

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